VISIT…

Chapter 15

Compressors and Gas Engines

As is implied by the term "compressor," we are dealing here with machinery that elevates the pressure of a compressible process fluid, typically air, or a host of other gases. Dynamic compressors are based on the principle of imparting velocity to a gas stream and then converting this velocity energy into pressure energy. In contrast, positive displacement compressors confine a certain inlet volume of gas in a given space and subsequently elevate this trapped amount of gas to some higher pressure level.

The overwhelming majority of compressors in either category incorporate moving and/or sliding components. Only "static" jet compressors (ejectors) and late 20th- and early 21st-century oil-free machines whose rotors are suspended in magnetic or air bearings are exempt from the need for bearing lubrication.

Dynamic turbomachinery, such as the equipment depicted in Figures 15-1 through 15-3, requires lubrication of bearings and seals. To date, the majority of dynamic compressors continue to utilize liquid-lubricated seals, items 1 through 3 of Figure 15-4. Only labyrinth seals or gas-lubricated seals (item 4, Figure 15-4) operate without a liquid film separating the faces. On the more conventional liquid-lubricated seals, the bearing and sealing lubricant are often the same, i.e., an R&O or hydraulic oil. However, this "seal oil" generally enters the supply port (Figure 15-5) at a higher pressure than would be needed to lubricate the bearings.

Positive displacement compressors are primarily represented by reciprocating piston machines, Figures 15-6 and 15-7. In addition, there are rotary piston blowers (Figure 15-8), sliding vane compressors (Figure 15-9), liquid ring compressors (Figure 15-10), helical screw (Figure 15-11) and perhaps a dozen hybrid machine types deserving the classification "positive displacement." Some of these frequently operate with discharge temperatures exceeding 163°C (325°F); therefore, the lubricating oil must have good oxidation stability. Also, in cases where the lubricant removes moisture that has condensed from the gas, the lubricant must have good demulsibility.

Whenever practical, the lube oil supplied to the bearing system ("running gear") is the same as the lube oil supplied to the compressor working space, i.e., cylinder, piston rod packing, vanes, lobes, etc. Nevertheless, at times it will be more appropriate to provide a different lubricant to this working space. In that case, separate lube supply systems are used for working space and running components.

Elsewhere in this text, the reader will find an overview of different means of applying the lubricant. These different means range from simple static sumps to elaborate circulating systems. Still, in virtually every case bearings and sliding components require lubrication, and on major machinery this lubrication is generally applied with the help of a circulating oil system.

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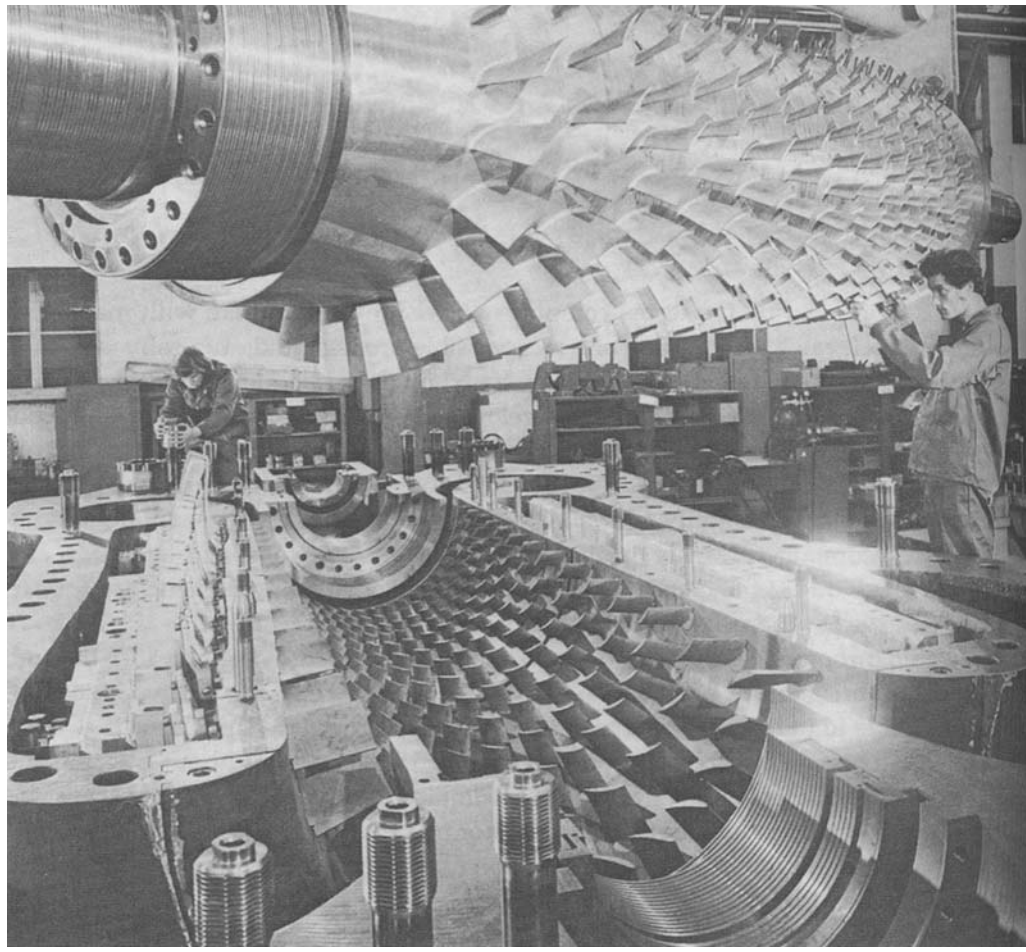

Figure 15-1. Axial turbocompressor being assembled. (Source: Sulzer Brothers, Winterthur, Switzerland)

LUBRICATION SYSTEM

The lube oil system (Figure 15-12) supplies oil to the compressor and driver bearings and to the gears and couplings. The lube oil starts off in the reservoir, from where it is drawn by the pumps and fed under pressure through coolers and filters to the bearings. On leaving the bearings the oil drains back to the reservoir.

The reservoir is designed to permit circulation of its entire contents between eight to 12 times per hour. Oil level and temperature are constantly monitored. The oil can be preheated electrically or indirectly by steam for starting up at low temperatures. A thermostat with surface temperature limiter prevents overheating of the oil. The reservoir is vented.

Oil is normally circulated by the main oil pump. An auxiliary pump serves as standby, as illustrated in Figure 15-13. These two pumps generally have different types of drive, or power supplies. When both are driven electrically, they are connected to sepa-

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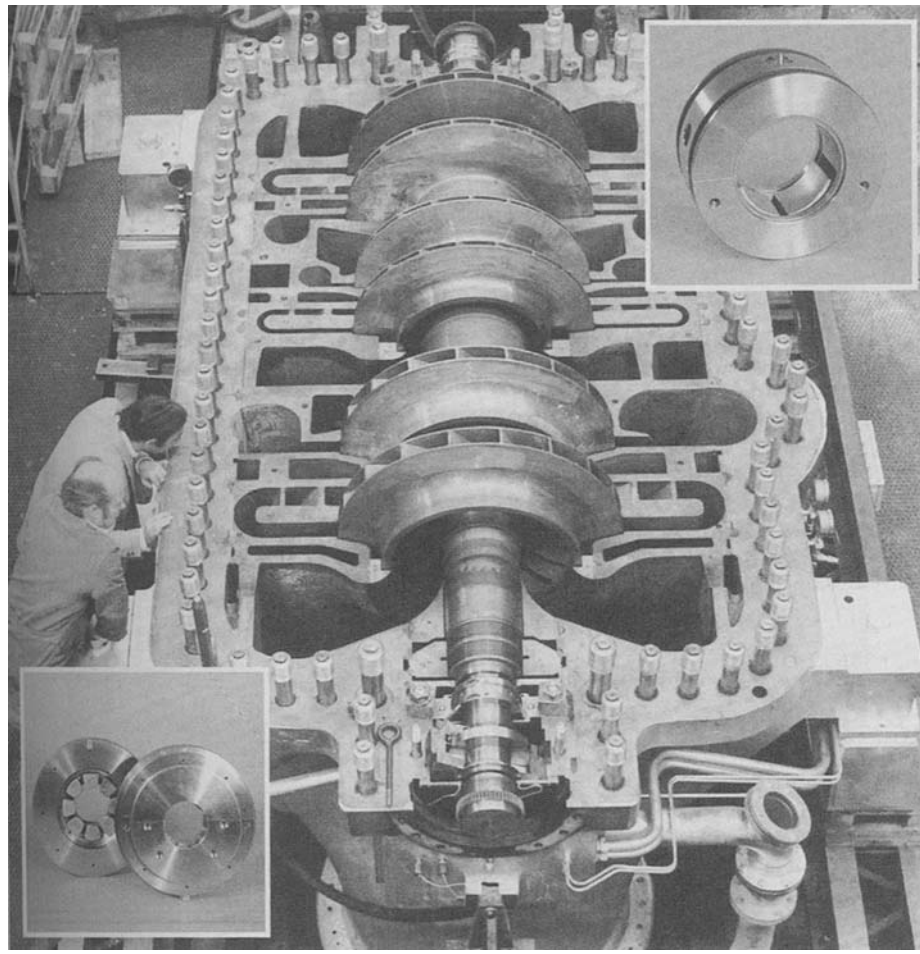

Figure 15-2. Centrifugal compressor with thrust bearing (inset, lower left) and radial bearing (inset, upper right). Source: GHH-Borsig, Berlin, Germany.

rate supply networks. On compressors with step-up gearboxes the main oil pump may be driven mechanically from the gearbox and the auxiliary pump then operates during the start-up and run-down phases of the compressor train. Relief valves protect both pumps from the effects of excessively high pressures. Check-valves prevent reverse flow of oil through the stationary pump.

Heat generated by friction in the bearings is transferred to the cooling medium in the oil coolers. The return temperature is monitored by a temperature switch. Air-cooled oil coolers may be employed as an alternative to water as a coolant. The former have long been used in regions where water is in short supply. Twin coolers with provision for changeover have filling and venting connections so that the standby cooler can be filled with oil prior to changing over. This eliminates the possibility of disturbances and damage due to air bubbles in the piping system. Twin oil filters with provision for changeover have the same facilities.

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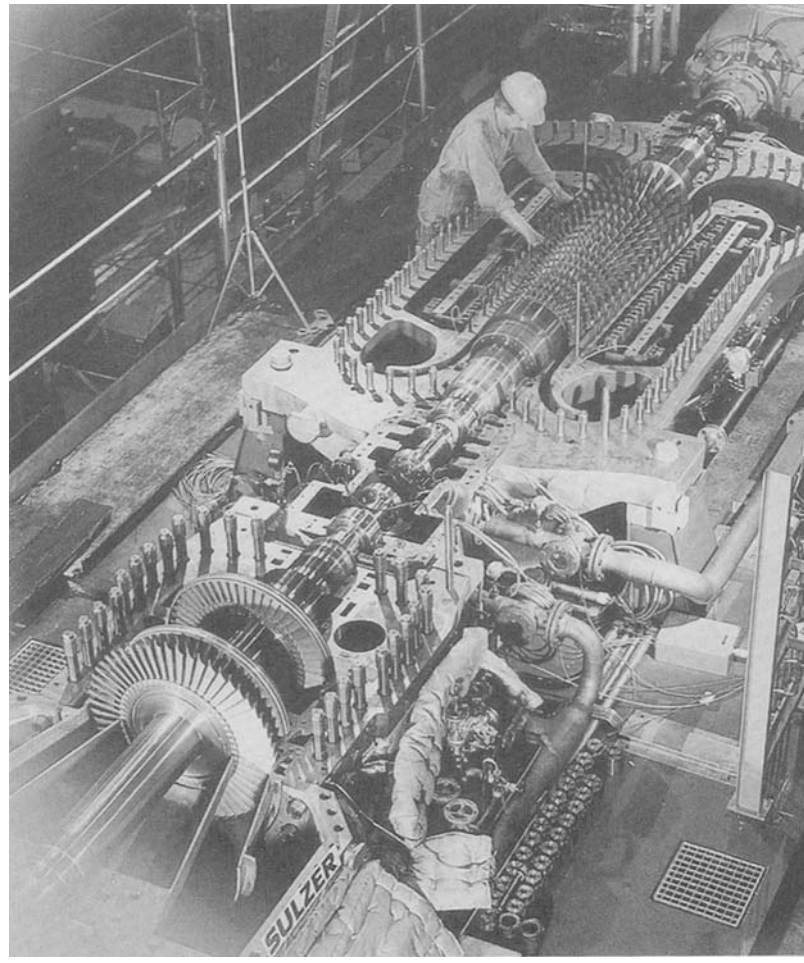

Figure 15-3. Turbotrain assembly in progress. (Source: Sulzer Brothers, Winterthur, Switzerland)

A pressure-regulating valve is controlled via the pressure downstream of the filters and maintains constant oil pressure by regulating the quantity of bypassed oil. The auxiliary oil pump is switched on by a pressure switch if the oil pressure falls. A second pressure switch shuts down the compressor train if the pressure still continues to fall.

The filters clean the lube oil before it reaches the lubrication points. A differential pressure gauge monitors the degree of fouling of the filters.

An overhead oil tank can be provided to ensure a supply of lubricant to the bearings in the event of faults while the compressor is being run down. A continuous flow of oil through an orifice maintains the header oil constantly at operating temperature. Should the pressure in the lube oil system fall, the non-return valve beneath the tank opens to provide a flow of oil.

The flow of oil to each bearing is regulated individually by orifices, particularly important for lubrication points requiring different pressures. Lube oil for the driver and other users is taken from branch lines.

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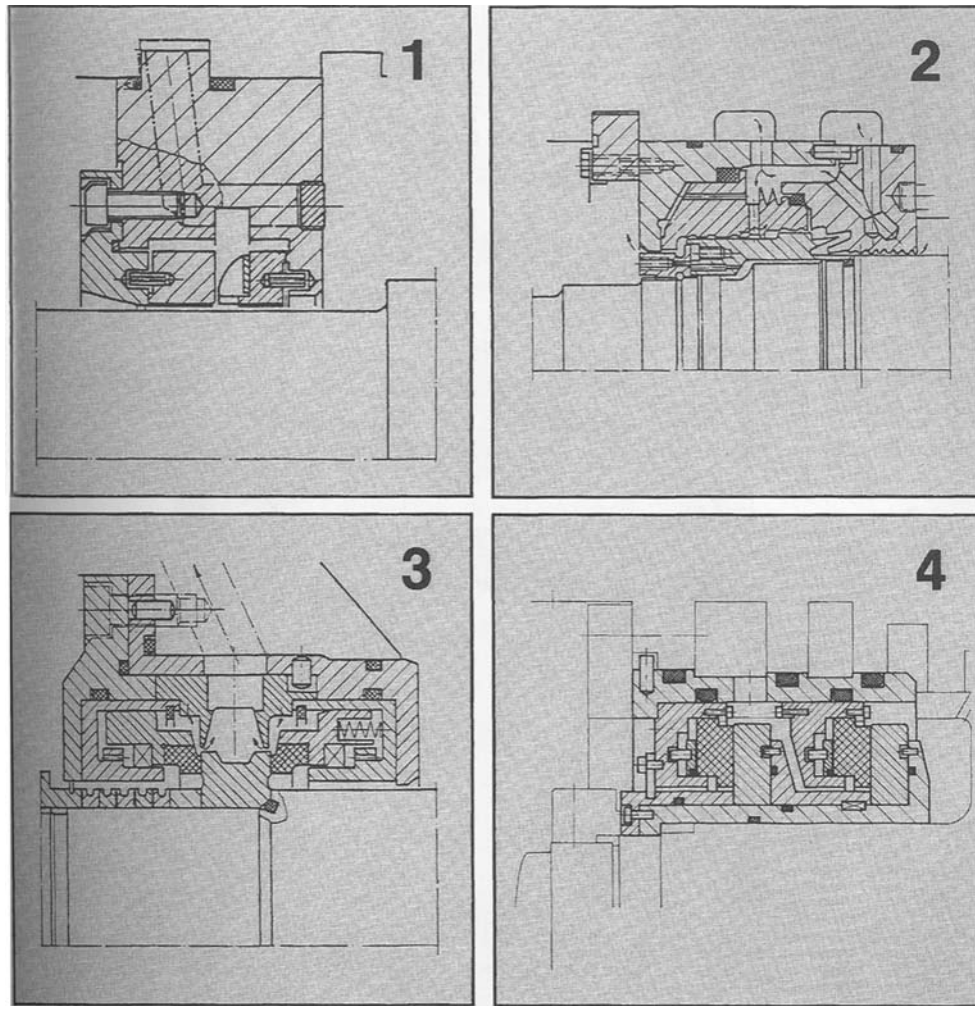

Figure 15-4. Seal geometries typically incorporated in dynamic compressors: 1 Floating ring seal; 2 Trapped bushing seal; 3 Liquid-lubricated mechanical contact seal; 4 Dry gas face seal. (Source: GHH-Borsig, Berlin, Germany)

When a hydraulic shaft position indicator is used, this is supplied with oil from the lube oil system.

Temperatures and pressures are measured at all important locations in the system; the readings can be taken locally or transmitted to a monitoring station.

Except for a few components, the lube oil system is conveniently installed in a packaged unit supplied complete and ready for installation. Oil pumps, coolers and filters are grouped around the oil reservoir on a common baseplate. Design and construction of the lube oil system takes into account relevant regulations and any special requirements.

Lube oil systems for reciprocating compressors are generally simpler than the system for dynamic compressors described above. Figure 15-14 represents the oil supply schematic for a conventional reciprocating machine.

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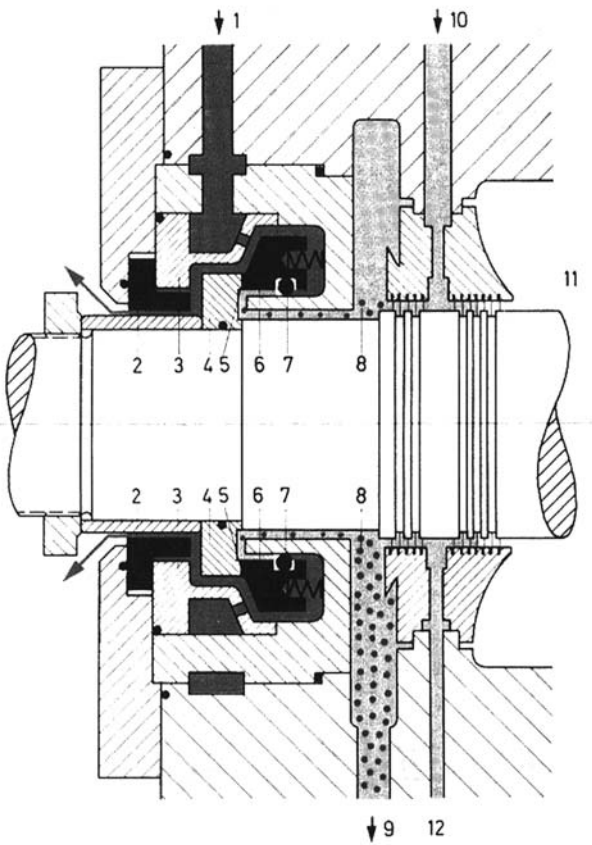

Mechanical contact seal
1 Seal oil supply
2 Floating ring
3 Distributor ring
4 Rotating ring on the shaft
5 Sealing interface
6 Carbon ring
7 O-ring
8 Buffer gas and seal oil collecting chamber
9 Drain from collecting chamber
10 Buffer gas supply
11 Process gas
12 Check drain

Mechanical contact seal

The mechanical contact seal employs a stationary carbon ring in sliding contact with a rotating ring manufactured from high-quality material with a special finish. A seal liquid is employed. This type of seal is also effective when the compressor is at standstill and the oil pumps have been shut down.

The main components are the carbon ring and the rotating ring for inward sealing. In the outboard direction a floating ring controls the flow of the seal liquid which cools the seal.

The seal liquid enters the seal via the supply pipe 1 and flushes the seal ring components via the holes in the distributor ring. The pressure of the liquid is higher than that of the gas, so that the carbon ring, under constant spring pressure, is always kept in sliding contact with the rotating ring. Some of the liquid wets the sliding surface 5 and reduces wear. Only a very small proportion of this liquid passes to the gas side.

A controlled flow of buffer gas flowing from the supply pipe 10 through a labyrinth to port 8 entrains this leakage liquid and leads it via outlet 9 to the separator.

O-rings fitted externally and within the seal reliably separate the buffer gas and seal liquid spaces.

Figure 15-5. Mechanical contact seal showing seal oil inlet at point 1. (Source: Mannesmann-Demag, Duisburg, Germany)

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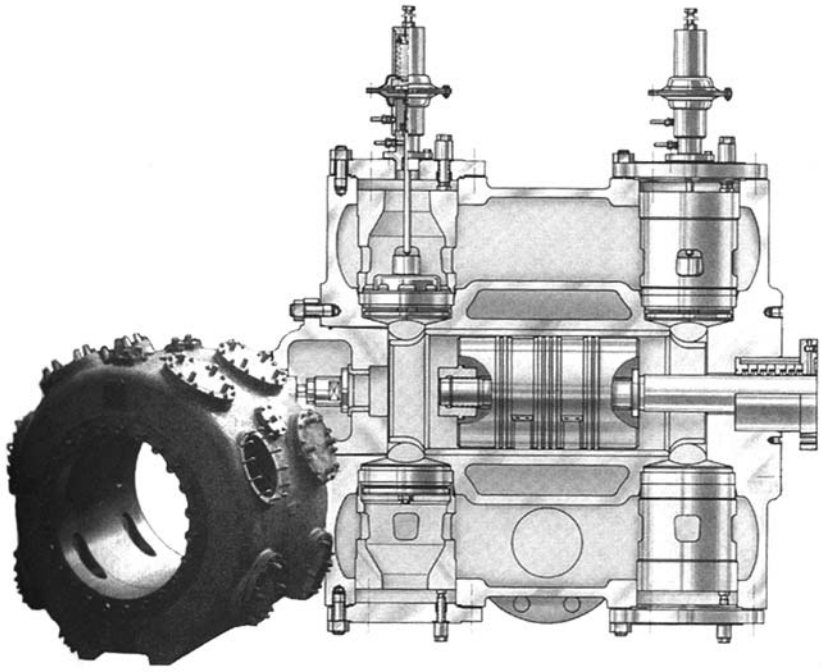

Figure 15-6. Reciprocating compressor cylinders require lubrication in the piston rod packing and piston ring areas. Source: GHH-Borsig, Berlin,

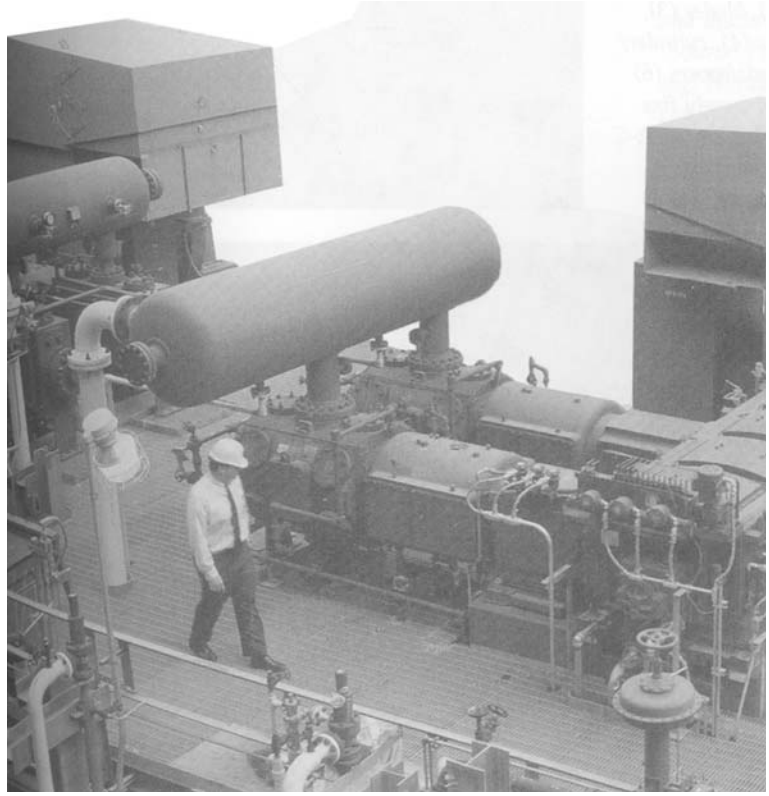

Figure 15-7. Reciprocating compressor installation. (Source: Dresser-Rand Company, Painted Post, New York)

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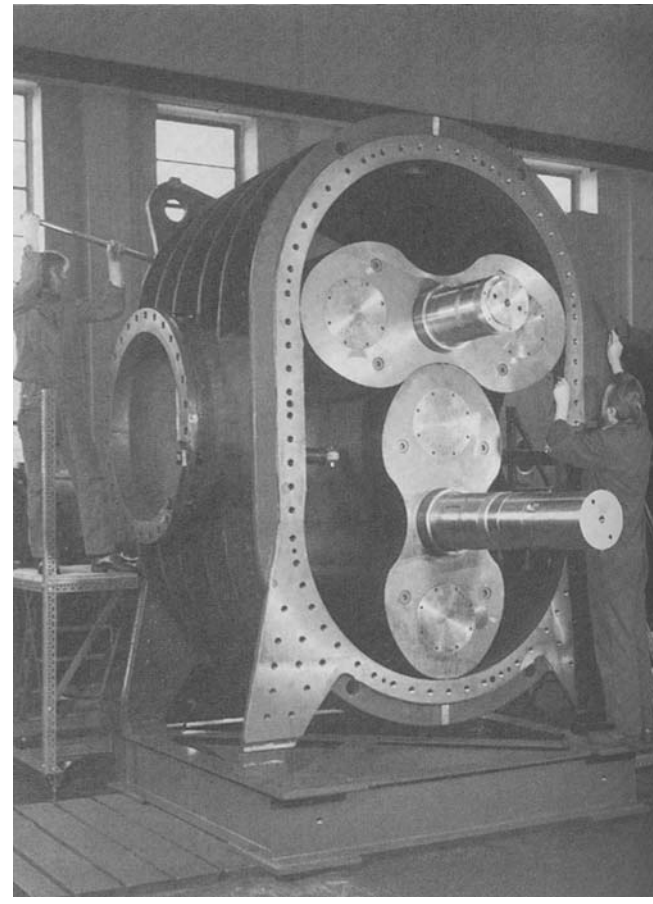
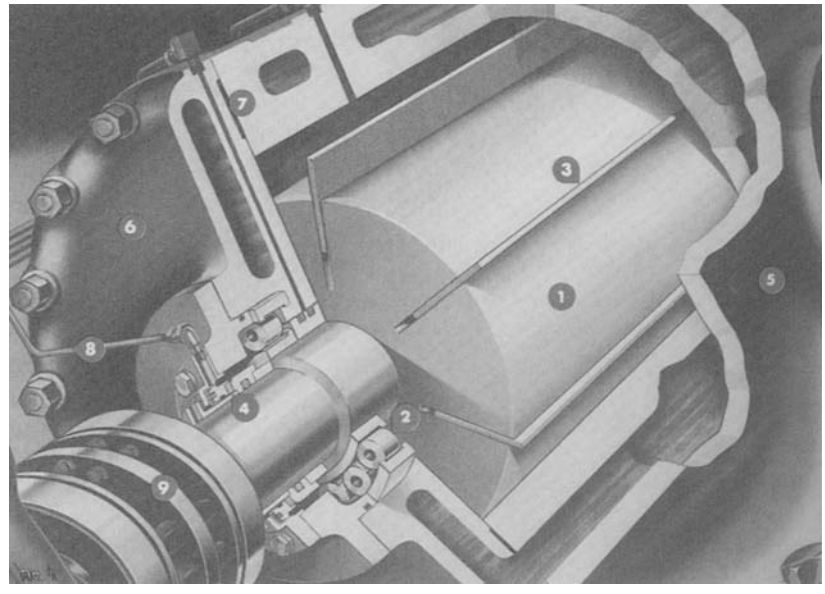


RIGHT: Figure 15-8. Large lobe-type rotary piston blower. (Source: Aerzen USA, Coatesville, Pennsylvania, USA)

BELOW: Figure 15-9. Sliding vane compressor and principal components: rotor and shaft (1), bearings (2), blades (3), mechanical seals (4), cylinder/ housing (5), heads/covers (6) gaskets (7), lube supply line (8), coupling (9). (Source: A-C Compressor Corporation, Appleton, Wisconsin, USA)



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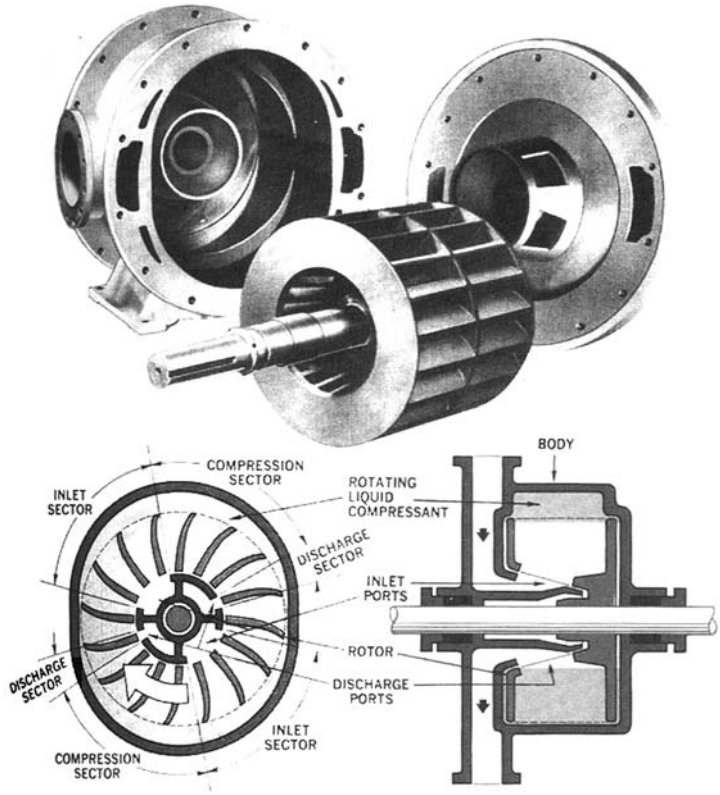

Figure 15-10. Liquid ring compressor with elongated casing (A), and schematic section at inlet and discharge sectors (B). (Source: Nash Engineering, Norwalk, Connecticut, USA)

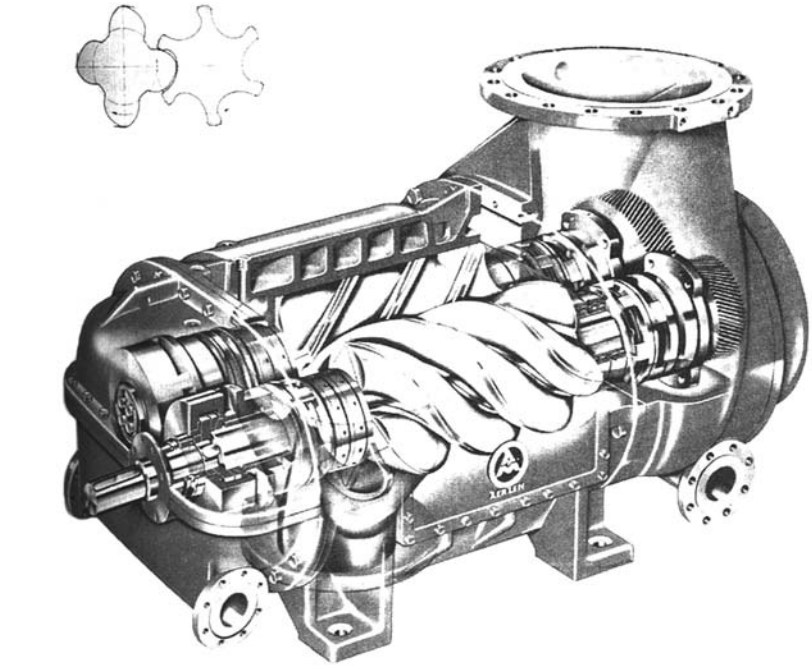

Figure 15-11. Helical screw compressor. (Source: Aerzen USA, Coatesville, Pennsylvania).

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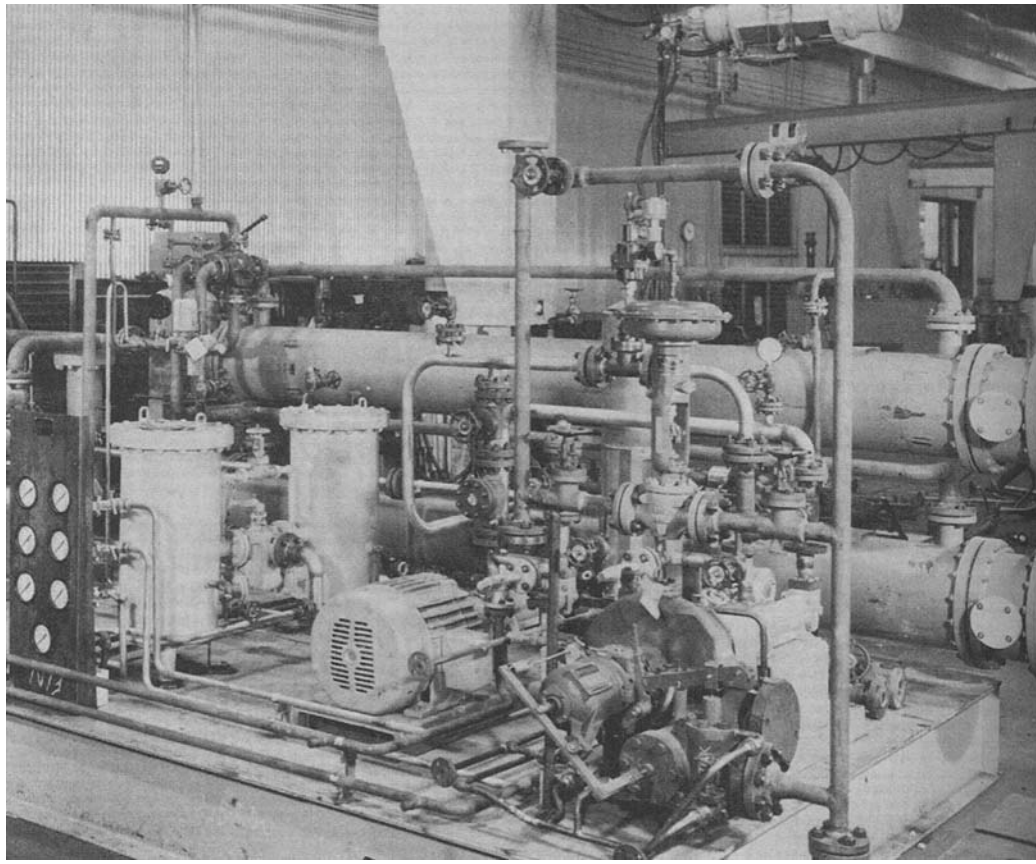

Figure 15-12. Lube/seal oil skid for a centrifugal compressor. (Source: Elliott Company, Jeannette, Pennsylvania).

SEAL OIL SYSTEM

The seal liquid system (Figure 15-15) supplies mechanical contact and floating ring seals with an adequate flow of seal liquid at all times, thus ensuring that they function correctly. An effective seal is provided at the settle-out pressure when the compressor is not running. The seal oil system may be combined with the lube oil system if the gas does not adversely affect the lubricating qualities of the oil or provided the oil made unserviceable by the gas does not return into the oil system.

There are two methods of combining lube oil and seal oil systems. In the first of these (Figure 15-16), the oil can be raised to the pressure required for lubrication purposes and part of it then raised further to the pressure needed for sealing (booster system.) Alternatively, all the oil is initially raised to the seal oil pressure and the flow of oil required for lubrication then reduced in pressure (combined system).

Starting in the main oil reservoir, the medium passes to the seals via the pumps, the twin oil coolers and the twin filters.

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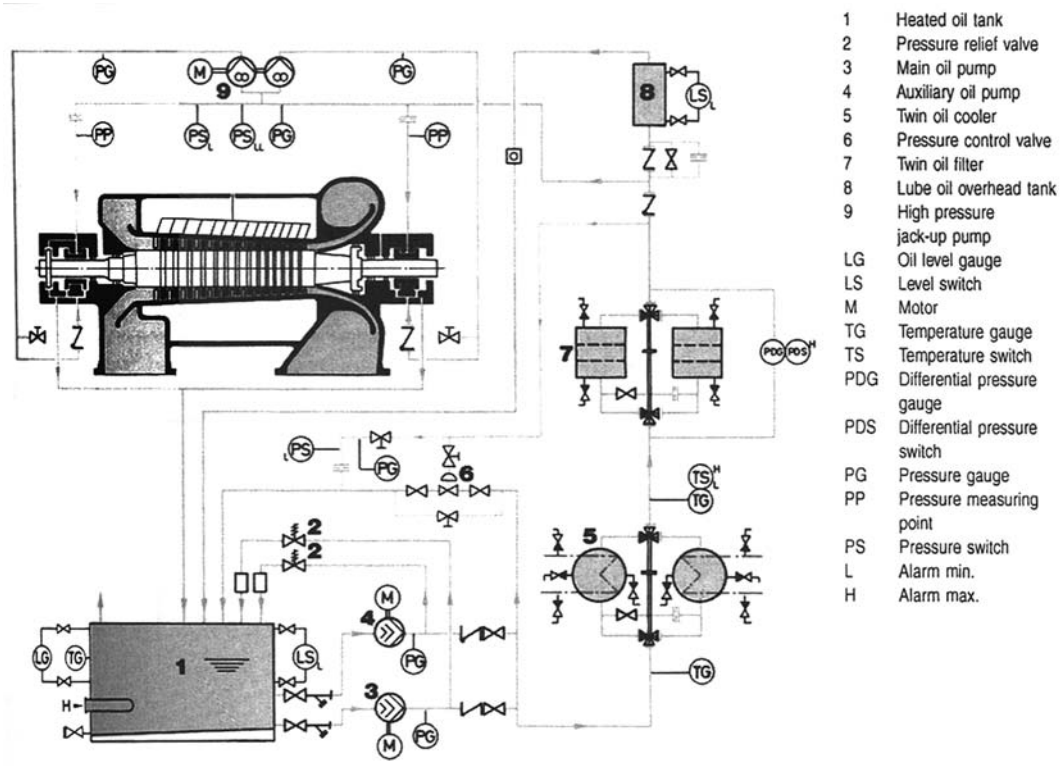

Figure 15-13. Typical lube oil schematic for turbomachinery. (Source: Mannesmann-Demag, Duisburg, Germany)

Instruments for monitoring the oil level and temperature are mounted on the reservoir. If necessary, the seal oil is heated; a thermostat with surface temperature limiter protects against excessively high temperatures.

Every system has a main oil pump and an auxiliary oil pump with independent drives. They are designed for a higher delivery rate than is actually needed by the seals. Safety valves protect the pumps and equipment downstream. Non-return valves after each pump prevent seal oil from flowing back to the reservoir through the non-running pumps.

The coolers dissipate the heat transferred to the seal oil. A temperature switch monitors the permissible temperature range.

The filters retain all impurities, the pressure drop across them being checked by a differential pressure indicator. Mechanical face seals and floating ring seals are supplied with seal oil at a defined differential pressure above the reference gas pressure (pressure within the inner seal drain). The flow of seal oil is regulated by a differential pressure regulating valve which, if there are changes in the reference gas pressure, regulates the pressure of the seal oil or, as shown in Figure 15-16, by a level-control valve that maintains a constant level in the overhead tank. The oil in the overhead tank is in contact with

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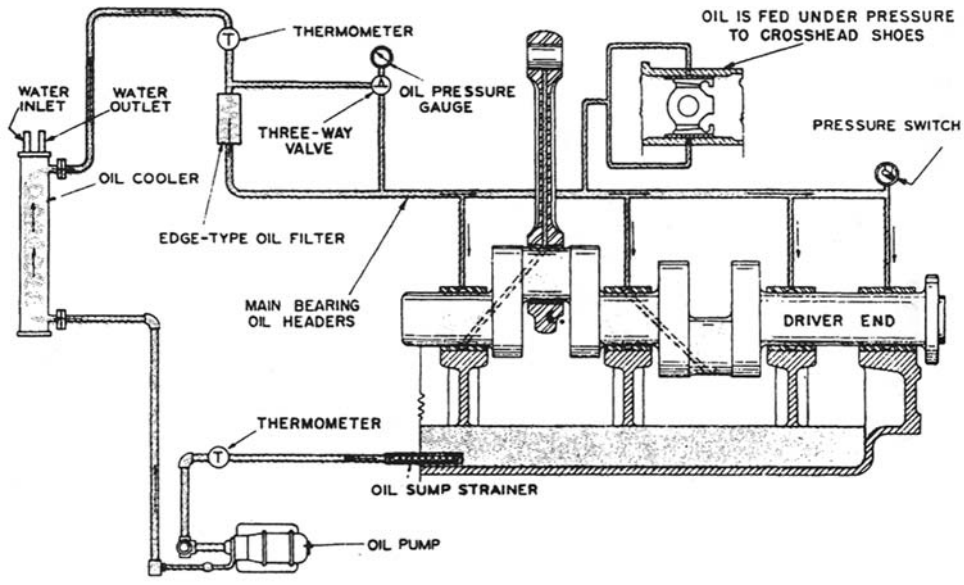

Figure 15-14. Reciprocating compressor lube oil system. (Source: Dresser-Rand, Painted Post, New York)

the reference gas pressure via a separate line. The static head provides the required pressure differential. In addition, the oil in the overhead tank compensates for pressure fluctuations and serves as a rundown supply if pressure is lost. If the level in the tank falls excessively, a level switch shuts down the compressor plant. There is a constant flow of oil through the overhead tank, and this heats the oil at all times.

For the mechanical contact seal the seal oil is kept at a constant differential pressure with respect to the reference gas by a regulating valve. As the name indicates, the mechanical contact seal provides a mechanical standstill seal when the compressor plant is shut down.

To prevent oil from gaining ingress to the compressor, the space between the oil drain and compression space is sealed by a flow of gas. The pressure of this sealing gas is above the pressure of the reference gas. A differential pressure indicator monitors the pressure differential.

The flow of seal oil divides in the compressor seals. Most of the flow returns under gravity to the reservoir. A small quantity passes through the inner seal ring to the inner drain, where it is exposed to the gas pressure. This oil, mixed with the buffer gas, is led to the separator system. On each side this consists of a separator and a condensate trap. The separated gas is led either to the flare stack or to the suction side of the compressor. The oil flows into a tank for degassing.

If oil is used as sealing liquid and can be used again, degassing is accelerated by heating or air or N_2 sparging. The oil is then returned to the reservoir. Sparging units perform on-stream purification of oil which can keep lubricants serviceable for very long time periods. Only if the oil becomes unusable is it led away for separate treatment or disposal.

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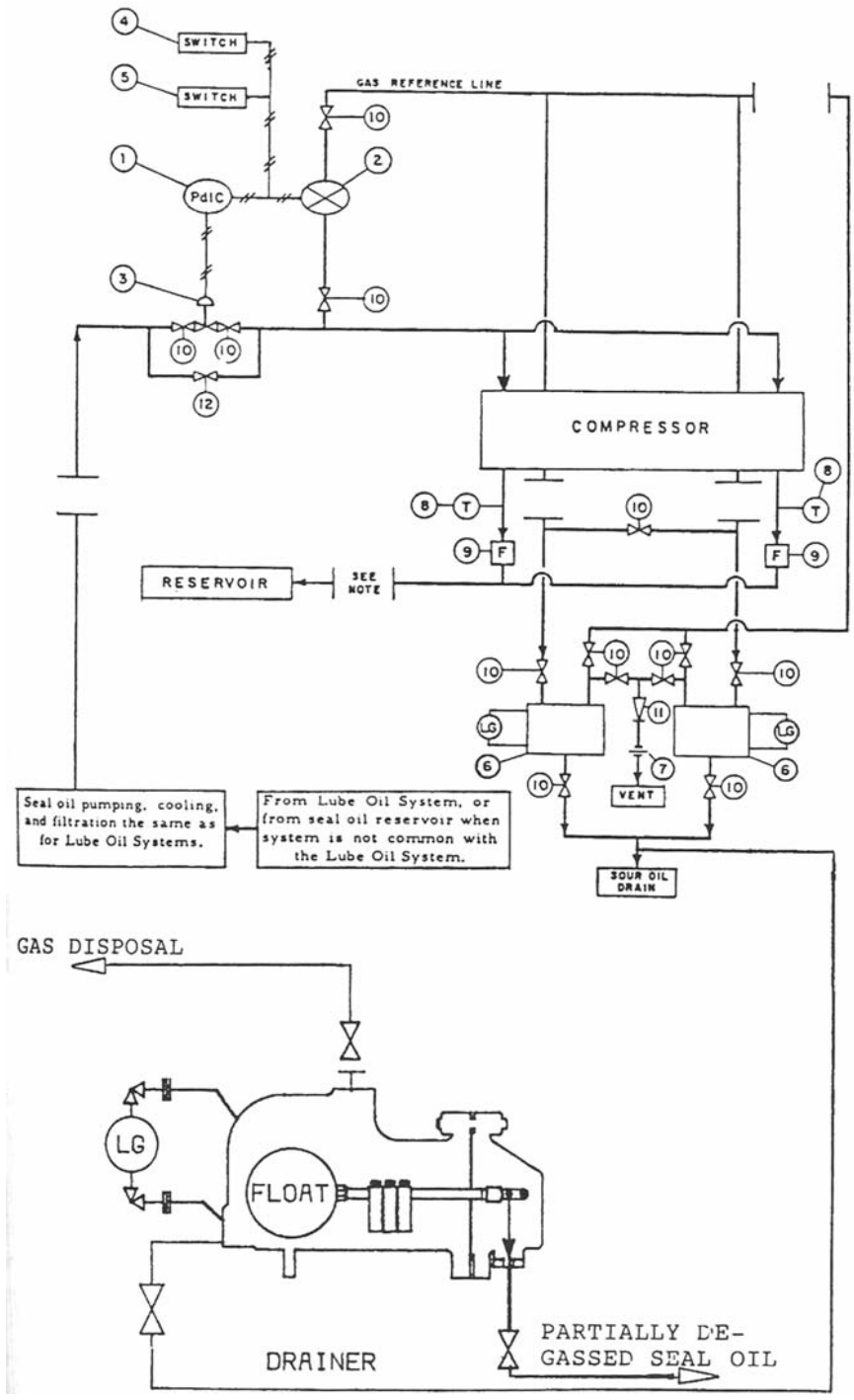

Figure 15-15. Compressor seal oil system schematic.

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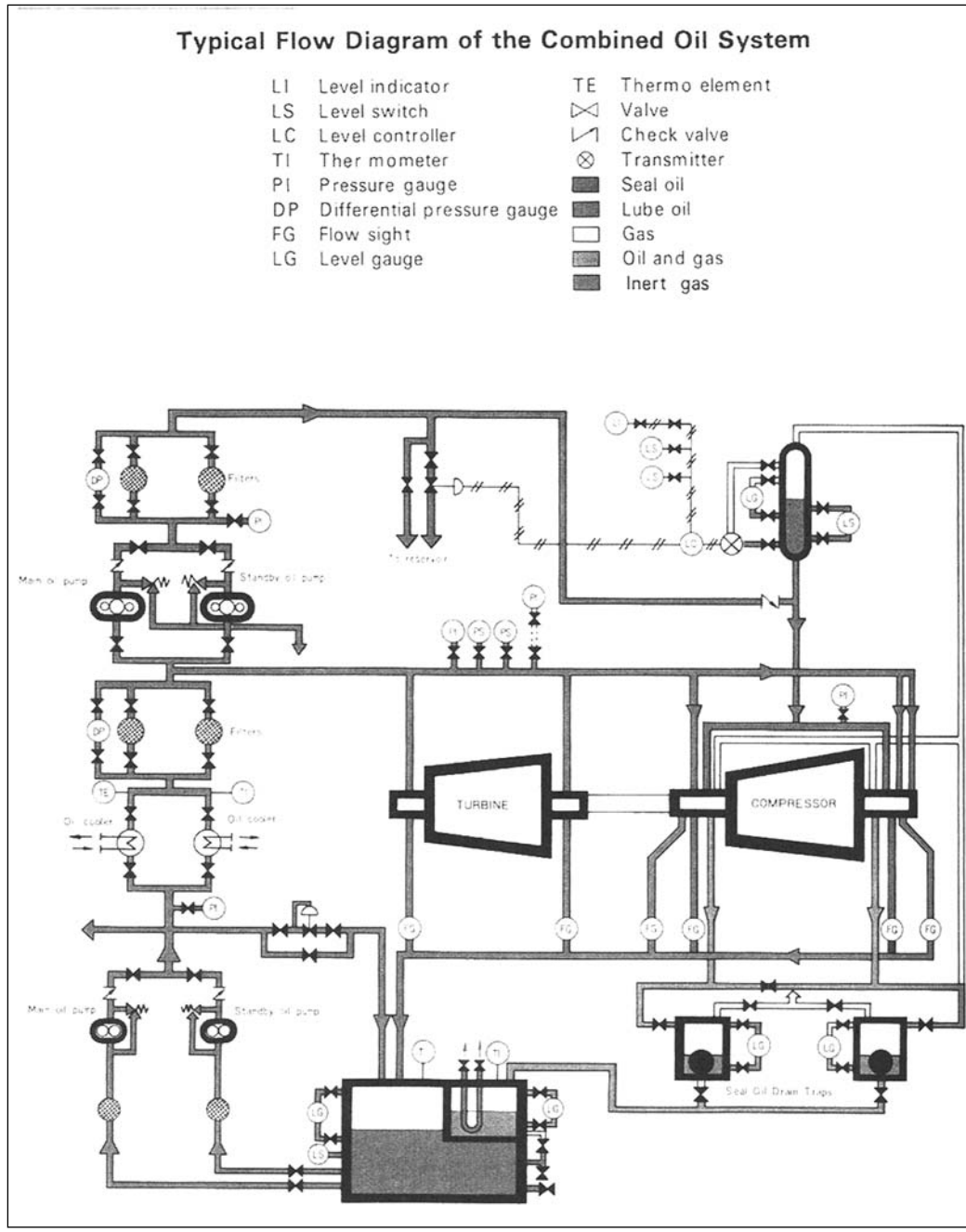

Figure 15-16. Combined lube and seal oil system for turbo compressors. (Source: Hitachi, Tokyo, Japan)

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The quantities of oil passing through the inner drain in modern centrifugal compressors are very small. Recall, however, that there is no seal oil system on compressors using dry gas seals (item 4, Figure 15-4).

Temperature and pressure measuring points with local or remote reading are provided at all major points of the seal liquid system.

COMPRESSOR LUBRICANTS

The overwhelming majority of compressors are best served by premium grade turbine oils with ISO viscosities 32 or 46. Many of these lubricants were discussed in Chapters 4 and 5 of this text. However, there are many different types of compressors and each manufacturer is likely to recommend only those lubricants that have been used on his test stand and at controlled user facilities.

Occasionally, compressor lubricants have to be formulated for exceptional severe-service performance. Several of these lubricants are described here for comparison purposes.

Exxon EXXCOLUB SLG is designed for cylinder and packing lubrication of reciprocating compressors, and EXXCOLUB SRS for rotary screw compressors. Their performance advantages include:

- Low hydrocarbon solubility
- Minimal lubricant viscosity loss
- Exceptional control of sludge, varnish, or lacquer formation
- High viscosity indexes
- Outstanding oxidative and thermal stability
- Excellent wear protection
- Low vapor pressure
- Excellent lubricity
- Good water solubility
- Non-poisoning to most catalysts

Formulated with a polyalkylene glycol (PAG) polymer basestock, EXXCOLUB exceeds the capabilities of petroleum-base and many synthetic-base lubricants in this severe-service application. The excellent oxidative and thermal stability of EXXCOLUB lubricants assure long service life in high-temperature operations. Their inherently high viscosity indexes, from 200 to 226, facilitate low-temperature startup and help maintain acceptable viscosity over a wide temperature range. EXXCOLUB lubricants have outstanding lubricity. Their proven additive technology provides enhanced protection against wear, oxidation, corrosion and foam.

Polyalkylene glycols are highly stable even at sustained high temperatures and thus have very low deposit-forming tendency. Any decomposition products that may form are soluble in the lubricant and do not tend to separate as sludge or contribute to the formation of varnish or lacquer.

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The low solubility of hydrocarbon, nitrogen, and CO_2 gases in EXXCOLUB helps maintain proper viscosity and, along with low vapor pressure, minimizes lubricant consumption. These lubricants also can tolerate significant amounts of moisture with little effect on lubrication efficacy.

Gases with which EXXCOLUB can be used include:

- Natural gas, nitrogen, CO_2
- LPG, such as propane and butane
- LNG, such as methane and ethane
- Hydrocarbon chemical gases, such as ethylene, propylene and butylene
- Landfill gas

EXXCOLUB lubricants are compatible with the elastomers and coatings listed in Table 15-1. If you are uncertain about lubricant compatibility, consult with the equipment manufacturer.

EXXCOLUB SLG 100 and EXXCOLUB SLG 190 are specifically designed for cylinder and packing lubrication of reciprocating compressors in hydrocarbon and chemical gas service. The viscosity of the 100 grade is equivalent to ISO 100; the viscosity of the 190 grade is intermediate between ISO 150 and ISO 220. Both grades offer the same high-performance advantages. Additionally, EXXCOLUB SLG 100 is specially formulated to be non-poisoning to most catalysts.

Table 15-1. EXXCOLUB elastomer and coatings compatibility. EXXCOLUB lubricants are compatible with a variety of elastomers and coatings.

	Recommended	Not Recommended
Elastomers	"Viton" A	Buna S
	"Kalrez"	"Hycar"
	Butyl K 53	Natural Black Rubber
	Buna N	"Hypalon"
	EPDM	
	Natural Gum Rubber	
	Neoprene	
	EPR Chloro Sulfonated	
	Polyethylene	
	"Thiokol" 3060	
	Polysulfide	
Coatings	Catalyzed Epoxy-Phenolic	Alkyd
	Modified Phenolic	Vinyl

Solubility Considerations

With a conventional mineral oil, compressed gas becomes dissolved in the oil, rapidly diluting it and lowering its viscosity. Additionally, lubricant dissolved in the gas can be carried away, depleting the lubricating film in the cylinder. All this can result in cylin-

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der scoring and higher wear rates in the packing, cylinder, and rings and rider bands.

In contrast to petroleum-base oils, EXXCOLUB SLG synthetic compressor lubricants have very low gas solubility and are thus much less affected by hydrocarbon, nitrogen and carbon dioxide gases. This distinctive feature minimizes lubricant viscosity loss, permitting long service life in a wide range of gas environments. In underground natural gas storage fields, the low hydrocarbon solubility of EXXCOLUB SLG has been proven highly advantageous in minimizing carry-over into the formation. It also has performed outstandingly in high-pressure (> 6000 psi) reciprocating compressors in nitrogen and hydrocarbon service.

Figure 15-17 compares the solubility of EXXCOLUB SLG in methane gas, compared with that of a polyalphaolefin (PAO) lubricant and a petroleum-base lubricant; EXXCOLUB SLG exhibits significantly lower solubility. Figure 15-18 compares the effect of methane gas pressure on the viscosity of EXXCOLUB SLG with that of a petroleum-base oil; EXXCOLUB is clearly superior in maintaining viscosity.

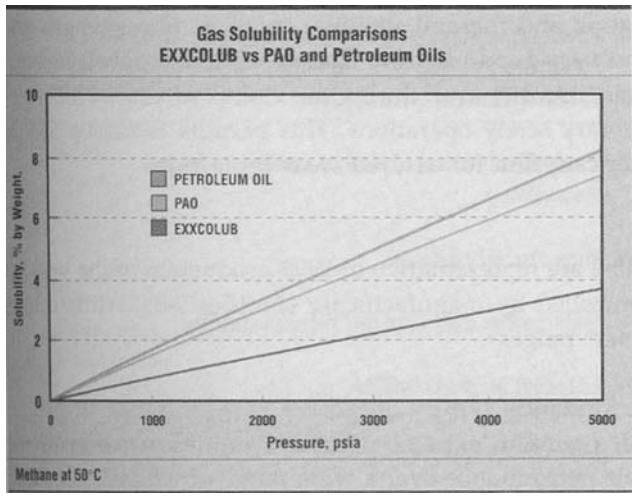

Figure 15-17. Gas solubility comparisons—EXXCOLUB vs. PAO and petroleum oils.

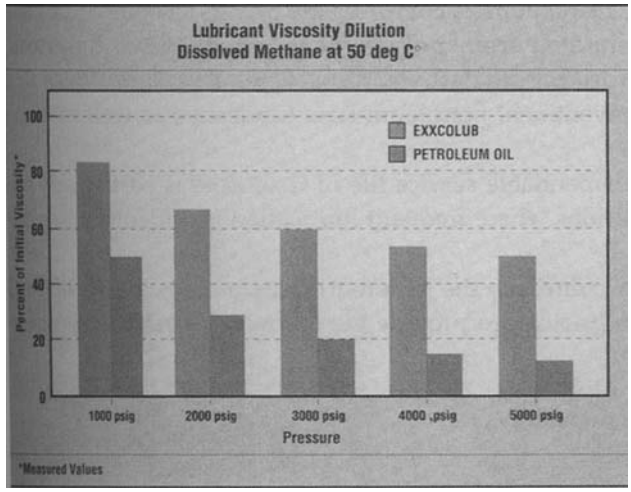

Figure 15-18. Lubricant viscosity dilution—EXXCOLUB vs. petroleum oil.

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EXXCOLUB SLG compressor lubricants further differ from a petroleum-base lubricant in being water soluble. This characteristic is highly desirable in oil field formation gas injection applications, since any lubricant carried over into the formation will stay dissolved and not plug the oil field formation. In addition to water solubility and low gas solubility, EXXCOLUB SLG also has high VI, good film strength, excellent oxidative and thermal stability and resistance to sludge formation.

Extra Oxidation Resistance Available

EXXCOLUB SRS is a premium lubricant specifically designed for rotary screw compressor applications. It shares the performance features of EXXCOLUB SLG, plus extra oxidation resistance for long-life service in the closed circulatory systems of rotary screw compressors. EXXCOLUB SRS also is an excellent lower-viscosity alternative to EXXCOLUB SLG in reciprocating compressors.

The performance of EXXCOLUB SRS in severe operating environments surpasses that of conventional petroleum-base oils and many comparable synthetic lubricants. The lubricant exhibits exceptional oxidation and thermal stability, excellent film strength and lubricity at high temperatures, and very good viscosity characteristics. Its low hydrocarbon solubility permits it to maintain viscosity even during the violent mixing of lubricant and gas that is characteristic of rotary screw operations. This permits EXXCOLUB SRS to maintain a dependably strong lubricant film for assured wear protection.

Typical Inspections

The values shown in Table 15-2 are representative of 1998 production of the various grades of EXXCOLUB. Some are controlled by manufacturing specifications, while others are not. All may vary within modest ranges.

GLYCOLUBE for Severe-Service Performance

Exxon GLYCOLUBE is a line of premium extreme-pressure, multi-purpose synthetic lubricants designed for dependable performance over a wide range of temperatures and operating conditions. GLYCOLUBE synthetic lubricants are well suited for many types of industrial applications, including gears, pumps, compressors, drivers, mobile equipment and anti-wear hydraulics. Formulated from polyalkylene glycol (PAG) basestock, GLYCOLUBE reliably lubricates and protects against wear in severe-service conditions that may exceed the capabilities of conventional petroleum-base lubricants, as well as many other synthetic-base lubricants.

The exceptionally long and dependable service life of GLYCOLUBE is particularly advantageous in out-of-the-way locations where frequent lubrication is difficult or impractical.

The GLYCOLUBE formulation combines the inherently superior qualities of PAG basestock with proven additive technology to provide the following outstanding performance features:

- Superb oxidative and thermal stability
- High viscosity indexes
- Low pour points for easier cold-temperature startup

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Table 15-2. Typical inspections for EXXCOLUB severe service compressor lubricants.

	EXXCOLUB SLG 100
Viscosity	
SUS @ 100°F (38°C)	400
210°F (99°C)	84.5
cSt @ 100°F (38°)	80.0
210°F (99°C)	16.3
Viscosity Index, ASTM D 2270	220
Pour Point, ASTM D 97, °F (°C)	-55 (-48)
Flash Point ASTM D 92*, °F (°C)	450 (232)
Water Content, maximum, %	0.15
Ash Content, maximum, %	0.01
Specific Gravity, 20/20°C	1.049
Weight per Gallon, lb (Liter, g)	
@ 60°F (16°C)	8.76 (1053)
@ 68°F (20°C)	8.73 (1050)

*Cleveland Open Cup

Grade	EXXCOLUB SLG 190
Viscosity, cSt	
@ 40°C	195
@ 100°C	35.1
@ 100°F	985
Viscosity Index	226
Pour point, °C(°F)	-43 (-45)
Flash point,	
Cleveland Open Cup, ASTM D 92, °C(°F)	304(580)
Pensky-Martens Closed Cup, ASTM D 93, °C(°F)	240(465)
Turbine Oil Rust Test, ASTM D 665	Pass
Copper Strip Corrosion Test	1a
FZG Extreme Pressure Test Stages Passed	12
Coefficient of Expansion, at 55°C	0.00079 per °C
Density, lb/gal, 20°C	8.75
Specific Gravity, 20/20°C (68/68°F)	1.05150

Grade	EXXCOLUB SRS 100	EXXCOLUB SRS 150
Viscosity, cSt		
@ 100°F(40°C)	91(84)	152(140)
@ 210°F(100°C)	16(15.6)	26(25.4)
SUS @ 100°F	425	700
Viscosity Index	200	215
Pour Point, °F(°C)	–45(–43)	-40(-40)
Specific Gravity, 20/20°C	1.045	1.047
Flash point, ASTM D 93, °F(°C)	390(199)	345(174)
Fire Point, ASTM D 92, °F(°C)	545(285)	575(302)

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- Excellent lubricity for enhanced resistance to friction and wear
- Extreme-pressure lubrication without chorine- or sulfur-containing additives
- Resistance to mechanical breakdown at high shear rates
- High resistance to sludge and varnish formation
- Non-corrosivity to metal surfaces/stain resistant to non-ferrous metals

Polyalkylene glycols are very stable even at sustained high temperatures and thus have a low deposit-forming tendency. Decomposition products that may form are soluble in the lubricant and do not tend to separate as sludge or contribute to the formation of varnish or lacquer.

The excellent oxidative and thermal stability of GLYCOLUBE lubricants assures long lubricant service life, even under heavy load, high-temperature conditions. These performance features are highly cost-effective in their ability to significantly reduce lubricant consumption and maintenance shutdowns.

The inherently high viscosity index of the PAG basestock both facilitates low-temperature startup and helps maintain acceptable viscosity over a wide temperature range. This eliminates the need for seasonal lubricant changeovers and simplifies lubricant inventories.

In compressor applications, the low solubility of hydrocarbon, nitrogen and CO_2 gases in GLYCOLUBE minimizes lubricant consumption and thereby maintains viscosity at effective levels. While suitable for all types of compressors, GLYCOLUBE is particularly recommended for centrifugal types. For reciprocating and rotary screw compressors, Exxon's EXXCOLUB line of lubricants is the first choice.

GLYCOLUBE lubricants are compatible with the elastomers and coatings listed in Table 15-3. If you are uncertain about lubricant compatibility, consult with the equipment manufacturer.

The exceptional versatility of GLYCOLUBE products may enable a plant to consolidate lubricants, thereby simplifying inventory and reducing the chances of lubricant misapplication. Some of the more common applications for GLYCOLUBE are listed in Table 15-4, while Table 15-5 gives typical specifications. For possible applications not listed here, the lubricant manufacturer's specialist work force can analyze specific lubrication needs and make an appropriate recommendation.

Procedures for Changing over to EXXCOLUB or GLYCOLUBE

When preparing to change over to EXXCOLUB or GLYCOLUBE, it is important to determine its compatibility with the former lubricant. Exxon can assist you in making this determination. If the two lubricants are shown to be incompatible, employ the following procedures *before* installing either lubricant. At a minimum, drain the old lubricant, clean the system to remove possible sludge and varnish, inspect seals and elastomers and replace the filters or clean the screens. If residual contamination is suspected, wipe or flush with a small amount of solvent or EXXCOLUB/GLYCOLUBE ; in new units, follow the same procedure to remove preservative or coating fluids.

After installing the lubricant, adjust the lubricators to deliver the manufacturer's recommended rate of lubricant. Check the filters or screens frequently during the early stages of operation, since EXXCOLUB and/or GLYCOLUBE will likely loosen residual sludge,

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Table 15-3. Compatibility chart for GLYCOLUBE lubricants.

	Recommended	Not Recommended
Elastomers	"Viton" A	Buna S
	"Kalrez"	"Hycar"
	Butyl K 53	Natural Black Rubber
	Buna N	"Hypalon"
	EPDM	
	Natural Gum Rubber	
	Neoprene	
	EPR Chloro Sulfonated Polyethylene	
	"Thiokol" 3060 Polysulfide	
Coatings	Catalyzed Epoxy-Phenolic	Alkyd
	Modified Phenolic	Vinyl

Table 15-4. Typical inspections for GLYCOLUBE lubricants. The values shown here are representative of current production. Some are controlled by manufacturing specifications, while others are not. All may vary within modest ranges.

	GLYCOLUBE Lubricants						
Property	**32**	**46**	**68**	**150**	**220**	**460**	**680**
Viscosity, ISO Grade, cSt	32	46	68	150	220	460	680
@ 100°F	39	52	66	143	263	389	615
@210°F	6.8	9.0	11.0	21.9	39.0	55.8	85.9
Viscosity Index	160	170	174	193	212	220	235
Pour point, °C(°F)	-43(-45)	-40(-40)	-40(-40)	-32)-25)	-29(-20)	-29(-20)	-27(-17)
Flash point, °C(°F)							
Pensky-Martens Closed Cup[1]	191(375)	138(280)	218(425)	166(330)	221(430)	183(362)	193(380)
Cleveland Open Cup[2]	246(475)	254(490)	277(530)	279(535)	291(555)	293(560)	282(540)
Water Content, % by wt	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Weight per Gallon at 60°F, lb	8.24	8.28	8.31	8.36	8.37	8.38	8.41
"Falex" Wear Test[3], Failure Load, psi	2900	2900	2900	2900	2900	2900	2900
Steam Turbine Rust Test[4],	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Copper Strip Corrosion Test[5]	1a	1a	1a	1a	1a	1a	1a
Coefficient of Friction[6]	0.0184						
Foam Tendency[7]							
@ 75°F	0	0	0	0	0	0	0
@ 200°F	0	0	0	0	0	0	0
@ 75°F	0	0	0	0	0	0	0

[1]ASTM D 92
[2]ASTM D 93
[3]ASTM D 3704
[4]ASTM D 665
[5]ASTM D 130
[6]Phosphorus bronze on steel, determined by David Brown Gear Industries Limited.
[7]ASTM D 892

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Table 15-5. Applications for GLYCOLUBE lubricants.

EQUIPMENT	APPLICATIONS	GLYCOLUBE Lubricants 32	46	68	150	220	460	680
Compressors	Axial	√	√	√				
	Radial	√	√	√				
	Radial Integral Gear	√	√	√				
	Reciprocating Crosshead Cylinder, Packing & Crankcase)				√	√	√	√
	Reciprocating Diaphragm (Crankcase)				√	√	√	√
	Reciprocating Trunk (Crankcase)				√	√	√	√
	Rotary Liquid Ring Rotor	√	√	√				
	Rotary Lobe (Gears)	√	√	√	√	√	√	√
	Rotary Screw (Dry & Oil-Flooded)	√	√	√	√	√	√	√
	Rotary Vane (Rotor)	√	√	√	√	√	√	√
Drivers	Chain Drives	√	√	√	√	√	√	√
	Electric Motors (Fixed & Variable Speed)	√	√	√				
	Expansion Turbine	√	√	√				
	Fluid Drive Couplings	√	√	√				
	Gas Turbine	√	√	√				
	Generators	√	√	√				
	Hydraulic-Driven Turbine	√	√	√				
	Steam-Driven Turbine	√	√	√				
Gears	Gears of All Types	√	√	√	√	√	√	√
Hydraulics	Fluid Drive Couplings	√	√	√				
	Hydraulic-Driven Turbine	√	√	√				
	Hydrodynamic Hydraulic Systems	√	√	√				
	Hydrostatic Drives	√	√	√				
Mobile	Cherry Pickers	√	√	√	√	√	√	√
	End Loaders	√	√	√	√	√	√	√
	Tractors	√	√	√	√	√	√	√
Pumps	Axial Piston	√	√	√	√	√	√	√
	Bent Axial Piston	√	√	√	√	√	√	√
	Centrifugal	√	√	√	√	√	√	√
	Diaphragm	√	√	√	√	√	√	√
	Double Diaphragm Fluid	√	√	√	√	√	√	√
	External Gear	√	√	√	√	√	√	√
	Internal Gear	√	√	√	√	√	√	√
	Liquid Ring	√	√	√	√	√	√	√
	Radial Piston	√	√	√	√	√	√	√
	Reciprocating	√	√	√	√	√	√	√
	Reciprocating Diaphragm	√	√	√	√	√	√	√
	Rotary Lobe	√	√	√	√	√	√	√
	Rotary Screw	√	√	√	√	√	√	√
	Rotary Vane	√	√	√	√	√	√	√
	Triplex	√	√	√	√	√	√	√
Others	Calendars	√	√	√	√	√	√	√
	Conveyors	√	√	√	√	√	√	√
	Crushers	√	√	√	√	√	√	√
	Grinders	√	√	√	√	√	√	√

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varnish and paint. If the manufacturer's recommended grade of lubricant is not available, consult Table 15-6, later.

NOTE: In gearbox applications, after 24 hours of operation, the lubricant should be drained and the gearbox refilled.

It is also important to determine the compatibility of these lubricants with the elastomers and coatings in the system. For assistance in this determination, refer to the earlier Tables 15-1 and 15-3.

For Exxon's 1998-vintage recommendations on compressor lubricants, consult the following pages. Recall, however, that these Exxon lubricant recommendations are based on manufacturer recommendations or specifications contained in Exxon's MAC (Manufacturers' Acceptance and Classification) Sheets. **IMPORTANT: These recommendations are intended as a guide only. If there is a discrepancy between the recommendations given here and those provided in the equipment manufacturer's manual, the latter must take precedence.**

Before using a synthetic lubricant such as SYNESSTIC in any application, consult with the manufacturer to ensure compatibility with paints, elastomers, plastics, filter plugs, O-rings, etc. The Exxon representative can answer any questions regarding the use of SYNESSTIC synthetic industrial lubricants in any compressor not listed below.

Exxon Lubricant Recommendations for Compressors

Ro-Flo* Rotary Compressors
A-C COMPRESSOR CORPORATION
Appleton, Wisconsin

The type and grade of oil recommended by A-C Compressor for use with Ro-Flo units is usually indicated on the name plate by a letter and SAE number. The SAE number will normally correspond to that in the table below for the extended discharge gas temperature and for inlet gas temperatures above 32°F.

Discharge Gas Temp. °F	SAE Number
Below 200	20
200 to 250	30
250 to 300	40
Below 300	50

If gas handled is expected to condense and dilute the oil, use the next higher viscosity grade. Multi-viscosity grades of oil are recommended for air inlet temperatures below 32°F, as are lubricator reservoir heaters and thermostats. On multi-stage units, use the highest discharge temperature to select the oil viscosity.

A-C Compressor Oil Type	Exxon Lubricant
A	ZERICE N 68 or ZERICE 68
B	XD-3
C	TERESSTIC 100
D	No product
E	XD-3
R	No product
S	No product

Dry Screw Compressors

Rotary, axial flow (Models 67S, 85S, 85L, 105S, 105L, 132S, 132L, 165S, 165L, 200L and 250L)	TERESSTIC 32

** Ro-Flo is an A-C Compressor trademark*

ATLAS COPCO COMPRESSORS, INC. Holyoke, Massachusetts	Exxon Lubricant
Air Compressor Type	
BE – BT – IE	
Above -10°C	TERESSTIC 68 or TERESSTIC SHP 68 XD-3 10W or 20W-20
BP 3	TERESSTIC SHP 68
DR – DT – DA – Inclusive Pack	
Above -10°C	TERESSTIC 68 or TERESSTIC SHP 68 XD-3 10W or 20W-20
GA Pack – GA – GAR	
Above 25°C	NUTO H 68 or UNIVIS N 68
Between -10°C and 25°C	NUTO H 32 or UNIVIS N 32
Below 0°C	UNIVIS N 15
Above -15°C	TERESSTIC SHP 46
GA Pack – GR	
Above -15°C	TERESSTIC SHP 46
ZR-ZA Pack, ZR-ZA	
Above -10°C	NUTO H 68 or UNIVIS N 68
Below -5°C	NUTO H 32 or UNIVIS N 32
ST	XD-3 10W
XA – XAH	
Above 25°C	NUTO H 68 or UNIVIS N 68
Between -10°C and 25°C	NUTO H 32 or UNIVIS N 32
Below 0°C	UNIVIS N 15
XR – XRH – XRV	
Above -15°C	TERESSTIC SHP 46
MA(S) – PN(S) – PT(H)(S) – PTMS – XT	
Above -10°C	XD-3 20W-20 or 15W-40
Below -5°C	XD-3 10W
EA – ER – ET Inclusive Pack/Package	
Above -10°C	TERESSTIC 68 or TERESSTIC SHP 68 XD-3 10W or 20W-20

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Air Compressor Type	Exxon Lubricant
LE – LT (AE, AT, ME, MT)	
-25°C to 40°C	XD-3 10W
-35°C to 50°C	SYNESSTIC 32
-25°C to 40°C	TERESSTIC SHP 32
ZT	
Above 0°C	NUTO H 68 or UNIVIS N 68
Below 5°C	NUTO H 32 or UNIVIS N 32
Above -10°C	XD-3 20W-20
Below -5°C	XD-3 10W
All temperatures	TERESSTIC SHP 68
TE – Line Compressor	
Above 10°C	XD-3 20W-20 or 15W-40
Below 20°C	XD-3 10W-30 or 10W
C-N	XD-3 20W-20 or 30, TERESSTIC 68 or 100

Portable Rotary "Mono-Rotor" Air Compressors
(Equipment no longer manufactured)

Compressor oil reservoir	XD-3 20W-20
Compressed air cleaner	
Above 0°F	XD-3
0 to -40°F	(1)
Miscellaneous oil applications	XD-3
Wheel bearings Suction control shaft All other grease-lubricated points	RONEX MP, LIDOK EP 2, UNIREX N 2 or POLYREX
Engine crankcase Gasoline or Diesel	XD-3 (See engine manual for ambient temperature oil grade recommendation)

(1) *Consult Atlas COPCO*

CHAMPION PNEUMATIC MACHINERY COMPANY, INC.
Princeton, Illinois

Single- and Two-Stage Compressors

Crankcase and cylinders	
32°F to100°F	TERESSTIC 100

NOTE: Consult manufacturer for compressor operations below 32°F.

CHICAGO PNEUMATIC EQUIPMENT DIVISION
Franklin, Pennsylvania
(Chicago Pneumatic no longer manufactures this equipment, but many units remain in field use.)

Stationary Compressors and Vacuum Pumps

Crankcase lubrication (pressure and flood system)	
Above 90°F	TERESSTIC 150
30 °F to 90°F	TERESSTIC 100
-10°F to 30°F	ESSTIC 68
Crankcase lubrication (splash system)	
Above 90°F	TERESSTIC 100
30°F to 90°F	TERESSTIC 68
-10°F to 30°F	ESSTIC 32

continued next column

Stationary Compressors and Vacuum Pumps	Exxon Lubricant
Cylinder lubrication (force-feed lubricator)	
Pressures 0 to 1000 psi	
Type 1* gas service	TERESSTIC 68
Type 2* gas service	TERESSTIC 100
Type 3* gas service	AROX EP 150
Type 4* gas service	No product
Pressures 1000 to 2500 psi	
Type 1* gas service	TERESSTIC 150
Type 2* gas service	TERESSTIC 220
Type 3* gas service	AROX EP 150
Type 4* gas service	TERESSTIC 220
Type 5 – Chlorine, hydrogen chloride, oxygen, non-contaminated gases	Use no petroleum products for cylinder lubrication
Steam cylinder lubrication	
Steam temperature up to 610°F, pressure below 250 psia	CYLESSTIC TK 460
Steam temperature above 610°F, pressure above 250 psia	
Saturated steam	CYLESSTIC TK 1000
Superheated steam	CANTHUS 1000

Portable Compressors

Reciprocating types	
Above 32°F	TERESSTIC 100
Below 32°F	TERESSTIC 68
Rotary "Power Vane"	SUPERFLO ATF(1) or TERESSTIC 32
Rotary "Singl-Screw" (Cylindrical)	TERESSTIC 32, 33 or 46(2)
Rotary "Singl-Screw" (Conical)	
Pressure up to 150 psi	SUPERFLO ATF or TERESSTIC 32, 33 or 46
Pressure above 150 psi	ETO 2380

* Type of gas service:
Type 1 – Dry gases, not carrying suspended liquids but may carry liquids that remain in the superheated state during the compression cycle, CO_2, N_2 helium, neon, and other inert gases, air, ammonia, hydrogen, methane
Type 2 – Hydrocarbon gases, such as butane, propane, butadiene, ethylene and nitrous oxide
Type 3 – Where water carry-over is a problem, in instances where wet gases are compressed, and when hydrogen sulfide is compressed
Type 4 – Methyl chloride, ethyl chloride, Freon, sulfur dioxide

(1) SUPERFLO ATF recommended for 2000-hour service.
(2) 1000-hour service maximum.

COMPAIR KELLOGG
Division of Robert Shaw Controls Company
Independence, Virginia

KRS Industrial Rotary Screw and Vane Compressors(1)

Compressor oil	TERESSTIC 46, XD-3 20W-20, SUPERFLO ATF or SYNESSTIC 68

Reciprocating Compressor

Compressor oil	
Ambient or room temperature	
55°F to 120°F	TERESSTIC 100
32°F to 55°F	TERESSTIC 68
0°F to 32°F	TERESSTIC 32 or 33

Hydrovane(1)

Compressor oil	XD-3 40 or SYNESSTIC 100

(1) Equipment manufacturer recommends their private label diester-based lubricants.

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DAVEY COMPRESSOR COMPANY **Division of KECO Industries, Inc.** **Florence, Kentucky**	Exxon Lubricant
PERMAVANE ROTARY COMPRESSORS **Air-Auto Models 85RA, 85PRAB, 125 PRAP, 160RPAB, 125RA and 160RA.** **Industrial Stationary Models 15BA, 20BA, 25BA, 25BW, 30BA, 30BW, 40BA, 40BW, 50BA, 50BW, 75DA, 75DW, 100DA, 100DW, 150DA, 150DW.**	
Compressor reservoir	
Over 40°F	XD-3 EXTRA 30 or XD-3 30
Below 40°F	XD-3 EXTRA 30 or XD-3 10W-30
Oil bath air cleaner (if supplied) Speed control	Use same type and grade as compressor
Portable Models 85RPV, 125PVC, 150RPV, 160RPV, 190RPG, 190RPD, 200PVC, 250RPV, 365RPV, 600RPV, and 750RPV.	
Compressor reservoir	
Over 40°F	XD-3 EXTRA 30 or XD-3 30
Below 40°F	XD-3 EXTRA 30 or XD-3 10W-30
Engine crankcase	Follow engine manufacturer's recommendations
Speed control Oil filter Air cleaner Other hand oiling applications	Use same type and grade as compressor
Wheel bearings Spring shackles Other grease applications	RONEX MP or LIDOK EP 2
PORTABLE RECIPROCATING COMPRESSORS **Models 66RMP, 64DDC, 84DDC, 33RME**	
Compressor crankcase	
Above 90°F	XD-3 30
32°F to 90°F	XD-3 20W-20
15°F to 32°F	XD-3 10W
Engine crankcase	Use same oil as compressor or follow engine manufacturer's recommendations
Compressor and engine air cleaners Starter and generator Other hand oiling applications	Use same type and grade as compressor
Unloader cylinders, water pump, spring shackles, wheel bearings All other grease applications	RONEX MP or LIDOK EP 2
Magneto	
Oil-lubricated	ESSTIC 32
Grease-lubricated	RONEX

NOTE: If the intake of any of the compressors shown above is in a location of high humidity or if any of the compressors is not equipped with a thermal bypass valve, use TERESSTIC 68 or ESSTIC 68 in the compressor reservoir.

DELAVAL TURBINE DIVISION **IMO Industries, Inc.** **(Formerly TransAmerica Delaval, Inc.)** **Trenton, New Jersey**	
Centrifugal Compressors	
Direct drive and normally loaded high-speed geared units	
With and without oil seals and not in NH3 refrigeration service	TERESSTIC 32 or 33
With oil seals and in NH3 refrigeration service	No product
All units	
Grease-lubricated parts	RONEX MP, LIDOK EP 2, UNIREX N 2 or POLYREX

DEVILBISS AIR COMPRESSOR PRODUCTS **Division of ITW Canada** **Barrie, Ontario, Canada**	**Exxon Lubricant**
Compressor Models No. 120, 121, 123, 130, 220, 225, 230, 235, 330, 342, 432, 445, 1202, 44633, 44642 and 44643	
Compressor crankcase	
Below 40°F	TERESSTIC 32 or 33
Above 40°F	TERESSTIC 46
Above 90°F	TERESSTIC 68

ELLIOTT COMPANY **United Technologies Corporation** **Jeannette, Pennsylvania**	
Centrifugal Compressors	
Bearings Seals Couplings	TERESSTIC 32
Axial Compressors	
Bearings	TERESSTIC 32

FULLER-KOVAKO CORPORATION **Bethlehem, Pennsylvania**	
Air* Service **(Normal Room Temperature, 60°F to 90°F)**	
Discharge temperature, 250°F to 325°F (Usually atmospheric to 30 psig or higher)	XD-3 40
Abnormal discharge air temperature above 325°F	SYNESSTIC 100**

* For gases other than air, refer to Fuller-Kovako.
** Check with Fuller-Kovako for compatibility with various models.

GARDNER DENVER COMPRESSORS MACHINERY, INC. **Quincy, Illinois**	
Horizontal Air Compressors, Vacuum Pumps, Tandems, Duplex and Balance-Opposed Models RL, RX, RT, HA, HL, ML,MD,MBV,MCY, MDY	
Cylinders[1]	TERESSTIC 100
Power-end crankcase, main bearings, crankpin, crosshead pin, crosshead guide and shoes	
Below 32°F	TERESSTIC 32 or XD-3 10W
32°F to 90°F	TERESSTIC 68 or XD-3 20W-20
Above 90°F	TERESSTIC 100 or XD-3 30
Vertical and W Type Air Compressors, Vacuum Pumps, Water-Cooled and Air-Cooled, Models AA, AB, AC, AD, AS, AT, AV, LA, WA, WB, WC, WE, WF, WH, WR, WS, WT, WV, WX	
Cylinders, pistons, pins, rings, main bearings, and crankpin bearings	
Above 0°F	TERESSTIC 32
Below 90°F	TERESSTIC 68
Above 90°F	TERESSTIC 100
Rotary Portable Air Compressors, Vane Type, All Models RP	
Pump reservoir	SUPERFLO ATF
Rota-Screw, Flex-Air, Portable Air Compressors, All Models	
Pump reservoir	SUPERFLO ATF

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Electra-Screw, Electra-Saver Compressors, All Models	**Exxon Lubricant**
Pump reservoir	SUPERFLO ATF
Where periods of operation exceed 4 hours at discharge temperatures between 200°F and 210°F	No product

(1) If carbon or Teflon rings are used, no lubrication is required.

GAST MANUFACTURING GROUP
Benton Harbor, Michigan

Lubricated Compressors	
Ambient temperatures below 100°F	XD-3 10W
Ambient temperatures above 100°F	XD-3 20W-20

IMO INDUSTRIES, INC.
Deltex Division
(Formerly TransAmerica Delaval, Inc.)
Houston, Texas

Turbopac Units	
Gas generator, centrifugal compressor	
Common lube system	TURBO OIL 2380

INGERSOLL-RAND
Air Compressor Group
Davidson, North Carolina

PORTABLE COMPRESSORS – GYRO-FLO, SPIRO-FLO AND SUPER SPIRO-FLO	
XHP, HP, XP, P	
-10°F to 125°F	SUPERFLO ATF or XD-3 10W
-40°F to 125°F	(1)
XHP (300 psi)	
-10°F to 125°F	SUPERFLO ATF or TERESSTIC SHP 68
XHP (350 psi)	
-10°F to 100°F	TERESSTIC SHP 68
70°F to 125°F	TERESSTIC SHP 150
Engine Crankcases	
Gasoline / Diesel	See engine manufacturer's recommendations
Air cleaners / Oil-lubricated bearings and parts	Same oil as used in engine
Grease-lubricated bearings and bearings and chassis points (excluding wheel bearings)	RONEX MP, LIDOK EP 2, UNIREX N 2 or POLYREX
CENTAC CENTRIFUGAL COMPRESSOR	
Lubricating Oil[2]	TERESSTIC 32
ROTARY SCREW TYPE COMPRESSORS	
AXI compressors	
Oil reservoir	TERESSTIC 32, 46 or 68
RECIPROCATING AIR-COOLED COMPRESSORS	
Type 30 and Type 40 Compressors	
Crankcase lubrication	
Below 40°F[3]	TERESSTIC 32 or 33, or ESSTIC 32
40°F to 80°F	TERESSTIC 68 or ESSTIC 68
80°F to 125°F	TERESSTIC 150
Grease-Packed Bearings (All Models)	RONEX MP, LIDOK EP 2, UNIREX N 2 or POLYREX

(1) Consult Ingersol-Rand
(2) Centac Model CV-O requires Turbo Oil 2389
(3) Pour point of lubricant should be at least 10°F below ambient temperature at starting time.

THE JAEGER MACHINE COMPANY **Columbus, Ohio** (The Jaeger Machine Company no longer manufactures this equipment.)	**Exxon Lubricant**
Portable Rotary Compressors – "Roto-Air Plus" Models 75, 85, 125, 125/150, 250, 365, 600 and 900	
Engine crankcase	
Gasoline or diesel	XD-3*
Engine air cleaner (wet type)	Same oil as used in crankcase
Wheel bearings and other grease applications	RONEX MP or LIDOK EP 2
Air compressor oil	
-20°F and above – ambient temperature	NUTO H 32
Air compressor air cleaner	Same as compressor oil
Stationary Rotary Compressors – "Roto-Air Plus" Models 130, 260, 380 and 625	
Compressor motor bearings / Blower motor bearings	ANDOK B, RONEX MP or LIDOK EP 2
Air compressor oil / Air compressor air cleaner	Same as above for portable models
Stationary and Portable Reciprocating Compressors Models 75, 125, 185, 250, 365 and 600	
Engine crankcase	
Gasoline or diesel	XD-3*
Engine air cleaner	Same oil as used in crankcase
Air compressor oil	
Below 10°F	XD-3 10W
10°F to 32°F	XD-3 20W-20
32°F to 100°F	XD-3 30
Above 100°F	XD-3 40
Compressor air cleaner	XD-3 20W-20
All grease applications other than electric motor bearings	RONEX MP or LIDOK EP 2

* See engine builder's manual for ambient temperature oil grade recommendation

JOY MANUFACTURING COMPANY
Quincy, Illinois
(Joy Manufacturing Company is part of Gardner Denver Machinery, Inc.)

WL-80, WL-80H, and WL-81 Small Stationary Compressors	
Models 15, 20, 25, 30, 40, 50, 60, 75, 90, 100, 125	
Crankcase and air cleaners	
-10°F to 32°F ambient	XD-3 10W, 20W-20, TERESSTIC 46 or ESSTIC 68
32°F to 90°F ambient	XD-3 30 or TERESSTIC 100
Above 90°F ambient	XD-3 40 or TERESSTIC 150
Large Stationary Compressors	
Models WG, WGO, WGAP, WGAPO, WN, WNO, WNAP, WNAPO, WM, WMO, WR	
Crankcase and cylinders	
-10°F to 32°F ambient	ESSTIC 68 or TERESSTIC 46
32°F to 90°F ambient	TERESSTIC 77
Above 90°F ambient	TERESSTIC 100
Air filters – oil bath, stationary, traveling screen	
-10°F to 32°F ambient	ESSTIC 68
32°F to 90°F ambient	TERESSTIC 77
Above 90°F ambient	TERESSTIC 100

continued next page

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Gas Compressors	Exxon Lubricant
Models WB, WBJ, WBF	
Crankcase and cylinders	
(with dry, clean, and sweet gas)	
-10°F to 32°F ambient	ESSTIC 68 or TERESSTIC 46
32°F to 90°F ambient	TERESSTIC 77
Above 90°F ambient	TERESSTIC 100
Rotary Sliding Vane Portable Air Compressors	
Models RP, RPQ, and RPV	
-20°F and above ambient	TERESSTIC 32
Twistair Compressors	
Stationary Helical Screw:	
Models TA0180E thru TA070E	
+50°F to 100°F ambient	XD-3 10W, SUPERFLO ATF, TERESSTIC 32 or SYNESSTIC 32
Portable Helical Screw: Models RPS and RPQ	
Rotary Construction Screw:	
Models RCS0180 thru RCS1535	
-20°F to 120°F ambient	SUPERFLO ATF or SYNESSTIC 32
+30°F to 100°F ambient	TERESSTIC 32 or 33
-10°F to 100°F ambient	XD-3 10W

LeROI INTERNATIONAL, INC.
Sidney, Ohio

Portable and Stationary Screw Compressors	
Compressor Oil	
Single-stage screw – air ends Two-stage screw – air ends	TERESSTIC 32 or 33, NUTO H 32, UNIVIS N 32 or SYNESSTIC 32*
All screw compressors	
Engine oil – portable units Electric motors – portable and stationary units	See manufacturer's recommendations
Portable and Stationary Rotary Sliding Vane Compressors	
Compressor Oil	
With aluminum sliding vanes	SUPERFLO 10W-40
Without aluminum sliding vanes	TERESSTIC 32 or 33, NUTO H 32, UNIVIS N 32 or SYNESSTIC 32*
Engine Oil	
LeROI engines	
Above 60°F	SUPERFLO 10W-40 or XD-3 30
32°F to 60°F	XD-3 20W-20
Below 32°F	XD-3 10W or 10W-30
Other engine makes	See manufacturer's recommendations
Electric motors	See manufacturer's recommendations
Oil bath air cleaners (engines and compressors)	Refer to air cleaner decal or use engine oil
Drive coupling	
Portable compressors with spline drive	RONEX MP or LIDOK EP 2
All other sliding vane compressors	See manufacturer's recommendations
Portable Reciprocating Compressors	
Compressor Oil	
Single-stage units, including Tractair	
Above 60°F	XD-3 30
32°F to 60°F	XD-3 20W-20
Below 32°F	XD-3 10W or 10W-30
Two-stage units	
Above 60°F	TERESSTIC 100
32°F to 60°F	TERESSTIC 68 or ESSTIC 68
Below 32°F	TERESSTIC 32 or 33 or ESSTIC 32

continued next column

Engine Oil	Exxon Lubricant
Two-stage units	
LeROI engines	
Above 60°F	XD-3 30
32°F to 60°F	XD-3 20W-20
Below 32°F	XD-3 10W or 10W-30
Other engines	See manufacturer's recommendations
Oil bath air cleaners (engines & compressors)	See air cleaner decal
Large Stationary and Unit Type Reciprocating Compressors	
Compressor Oil	
S1, S2 and SDS units	
Above 60°F	TERESSTIC 100
32°F to 60°F	TERESSTIC 68 or ESSTIC 68
Below 32°F	TERESSTIC 32 or 33 or ESSTIC 32
VC, WC, VS, WS, Y AND G, and all "Series" units	
Above 32°F	TERESSTIC 68 or ESSTIC 68
0°F to 32°F	ESSTIC 32
Below 0°F	Use auxiliary heaters

NOTE: For cold weather operation, the lubricating oil should have a pour point 20°F below the lowest expected operating temperature.

* If SYNESSTIC is to be used, check with manufacturer for seal compatibility.

NORWALK COMPANY, INC.
South Norwalk, Connecticut

Cylinder Lubrication	
Air Service	
Dry suction conditions	TERESSTIC 150
Wet suction conditions	AROX EP 150
Gas Service	
Non-oxidizing and non-reactive gases in general service	
Dry suction conditions	TERESSTIC 150
Wet suction conditions	AROX EP 150
Non-oxidizing and non-reactive gases in refrigeration service	ZERICE 68
Chemically active gases – sulfur dioxide, chlorine, hydrogen chloride, etc.	No product
Oxygen, nitrous oxide	No product
Running Gear	
Lubrication systems	TERESSTIC 150

QUINCY COMPRESSOR DIVISION
Coltec Industries
Bay Minette, Alabama
Quincy, Illinois

Rotary (Helical Screw) Compressors – QS, QSI and QST, QA and QSA Series	
All ambient temperatures	SYNESSTIC 68(1)
Reciprocating Compressors – QR and QT Series	
Ambient temperatures	
Below 32°F	TERESSTIC 32 or 33(2)
32°F to 80°F	TERESSTIC 68, NUTO H 68(2) or SYNESSTIC 68(3)
80°F to 100°F	TERESSTIC 100(2) or SYNESSTIC 68(3)

(1) Mineral oils are no longer recommended by the equipment manufacturer. Equipment manufacturer recommends their own private-label PAO-based lubricant. If SYNESSTIC is to be used, compressor must be ordered from the factory specifying use of this lubricant in new unit. Seals compatible with diester lubricants must be installed.
(2) Equipment manufacturer recommends its own private-label mineral oil lubricants.
(3) If SYNESSTIC is to be installed in the field, compressor should be run-in for 200-300 hours on TERESSTIC 68 to seat rings. Drain completely and replace filters before installing SYNESSTIC. Seal conversion kits are available to ensure that seals are compatible with diester lubricants.

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ROOTS BLOWER DIVISION **Dresser Industries, Inc.** **Connersville, Indiana**	**Exxon Lubricant**
SPIRAXIAL COMPRESSORS	
Rolling-contact bearing type	
Ambient temperature	
32°F to 90°F	TERESSTIC 77
Below 32°F	SPINESSTIC 22
Sleeve bearing type	
Ambient temperature	
32°F to 90°F	TERESSTIC 32 or 33
Below 32°F	SPINESSTIC 22

SCHRAMM, INCORPORATED **West Chester, Pennsylvania** **(Compressors are no longer in production)**	
Gasoline and Diesel Engine Crankcase	XD-3 (See chart below for proper SAE grades)

	SAE Grades for Gasoline Engines		
	Above 90°F	**32°F to 90°F**	**Below 32°F**
Compressor Models			
20, 35, 50	30	20W-20	10W
60, 85, 100	30	20W-20	10W
125, 160, 250	40	30	20W-20
300, 375	40	30	20W-20

	SAE Grades for Buda Diesel Engines		
	Above 90°F	**32°F to 90°F**	**Below 32°F**
Compressor Models			
125, 420	40	30	20W-20

	Detroit Diesel and GM V-71 Engines		
	Above 32°F	**0°F to 30°F**	**-20°F to 0°F**
Compressor Models			
250, 300, 350 425/350, 600	30	20W-20	10W

THE SPENCER TURBINE COMPANY **Windsor, Connecticut**	
Standard Overhung Turbo-Blowers	
Motor bearings	
Rolling-contact bearings	POLYREX[1]
Four-Bearing Overhung Blowers	
Rolling-contact bearings	POLYREX[1]
Four-Bearing Outboard Blowers	
Rolling-contact bearings	POLYREX[1]

(1) Equipment manufacturer recommends a competitive product exclusively for machinery under warranty.

SULLAIR CORPORATION **Michigan City, Indiana**	
Rotary Screw Air Compressors	
Ambient temperature	
Below 90°F	XD-3 10W, SUPERFLO ATF or SPINESSTIC 32*
Above 90°F	XD-3 20W-20 or SPINESSTIC 32*
Exception: Model 24KT (Unit is filled with silicone fluid which is incompatible with petroleum or SYNESSTIC type fluids)	No product

continued next column

Refrigeration Compressors	ZERICE N 68 or ZERICE 68

* To avoid possible elastomer (seal) compatibility problems when using SYNESSTIC, contact Exxon Marketing Technical Services for a suitable flushing procedure.

THE TRANE COMPANY **La Crosse, Wisconsin**	**Exxon Lubricant**
Centrifugal Compressors	TERESSTIC 68, ZERICE N 68 or ZERICE 68
Reciprocating Compressors	
Models G, J and M (for refrigeration)	No product
Models E and F	ZERICE S 68
Models G (for air conditioning)	No product

WORTHINGTON COMPRESSORS **Dresser-Rand** **Houston, Texas**	
Stationary Water-Cooled Compressors	
Compressor Crankcase (frame) Lubrication	
For all frames, horizontal and vertical, BDC, CUB,DC, DYC, HB, ODC, ODP, OXP, VB, YC, and Blocair	TERESSTIC 100 or 150
Compressor Cylinder Lubrication	
For all compressor cylinders, separately lubricated, regardless of the type of frame upon which the cylinder is mounted:	
Discharge pressures 0 to 200 psig	
Cylinder diameters 0 to 20"	TERESSTIC 68
Cylinder diameters above 20"	TERESSTIC 150
Discharge pressures 200 to 1000 psig	
Cylinder diameters 0 to 10"	TERESSTIC 77
Cylinder diameters above 10"	TERESSTIC 150
Discharge pressures 1000 to 2500 psig	
Cylinder diameters 0 to 15"	TERESSTIC 150
Cylinder diameters 15 to 20"	TERESSTIC 320
Discharge pressures 2500 to 4000 psig	
Cylinder diameters 0 to 15"	TERESSTIC 320
Discharge pressures 4000 psig and above	
Cylinder diameters 0 to 15"	TERESSTIC 460

NOTE: Consult Dresser-Rand for the use of synthetic oil such as SYNESSTIC 68 or 100.

Refrigeration Type Compressors	
Cylinder lubrication	ZERICE N 68 or ZERICE 68
Steam-Driven Compressors	
Steam Power Cylinder Lubrication (Separately lubricated)	
Steam inlet temperature 600°F	CYLESSTIC 1500
Steam inlet temperature 500°F	CANTHUS 1000
Steam inlet temperature 400°F	CYLESSTIC TK 1000
Wet Steam	CYLESSTIC TK 1000
Centrifugal Compressors	
Lubrication systems for CAP 14-31, CAP 21-70, and CAP 85-120 packaged plant air centrifugal compressors and for EA air and nitrogen centrifugal compressors.	TERESSTIC 32 or 33

YORK INTERNATIONAL CORPORATION **York, Pennsylvania**	
Refrigerant compressor oil	
Ammonia compressors	ZERICE N 68 or ZERICE 68*

continued next page

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	Exxon Lubricant
Freon 12 compressors; evaporator temperature above -20°F	ZERICE N 68 or ZERICE 68*
All refrigerants; evaporator temperature above -20°F	No product
Hermetic compressors; evaporator temperature below -20°F	No product
Freon 12 automotive compressors	No product
All refrigerants; evaporator temperature below -20°F	No product

* Equipment manufacturer sells its own private-label oil and does not approve other oils. ZERICE N 68 or ZERICE 68 may be used as a substitute for either York "A" or "B" oils.

Cylinder-Oil Feed

In the lubrication of double-acting compressor cylinders, one of the most important factors is the rate of oil feed. The likelihood of over-lubrication is greater than that of supplying too little oil. Many problems associated with compressor operation can be overcome by preventing excessive lubrication. Proper control of the supply of oil to the cylinders is the most effective means of preventing the formation of objectionable deposits around valve ports, in ring grooves, and on cooler surfaces.

Under average conditions, one quart of oil will properly lubricate an operation equivalent to the sweep of a piston over 10,000,000 square feet of cylinder surface. In a 24-hour day, for example, the piston of a compressor with 5 square feet of cylinder area and operated at 500 rpm would sweep

$$5\text{ft}^2/\text{stroke} \times 2\text{ strokes/rev} \times 500\text{ rev/min} \times 1440\text{ min/24-hr day}$$

or 7,200,000 square feet per day. Such a compressor would normally require, therefore,

$$7{,}200{,}000/10{,}000{,}000$$

or 0.72 quarts of oil per 24-hour day. The oil feed rate for the average compressor, in quarts per 24-hour day, can thus be determined by the following formula:

$$\frac{\text{Bore (inches)} \times \text{Stroke (inches)} \times \text{rpm} \times 62.8}{10{,}000{,}000}$$

The same result can be obtained graphically from the chart, Figure 15-19.

Here, the value, 10,000,000 square feet, is a nominal one representative of average conditions. Under other conditions, it may be necessary to substitute a different value, one that can be expected to lie, however, between 6,000,000 and 15,000,000. Substitution may be made either in the formula or in the graph.

To determine whether oil is being fed to the cylinder at the computed rate, the compressor oil reservoir must first be filled at the beginning of a specified run. After a certain period of operation, the reservoir is refilled from a graduated container, so that the

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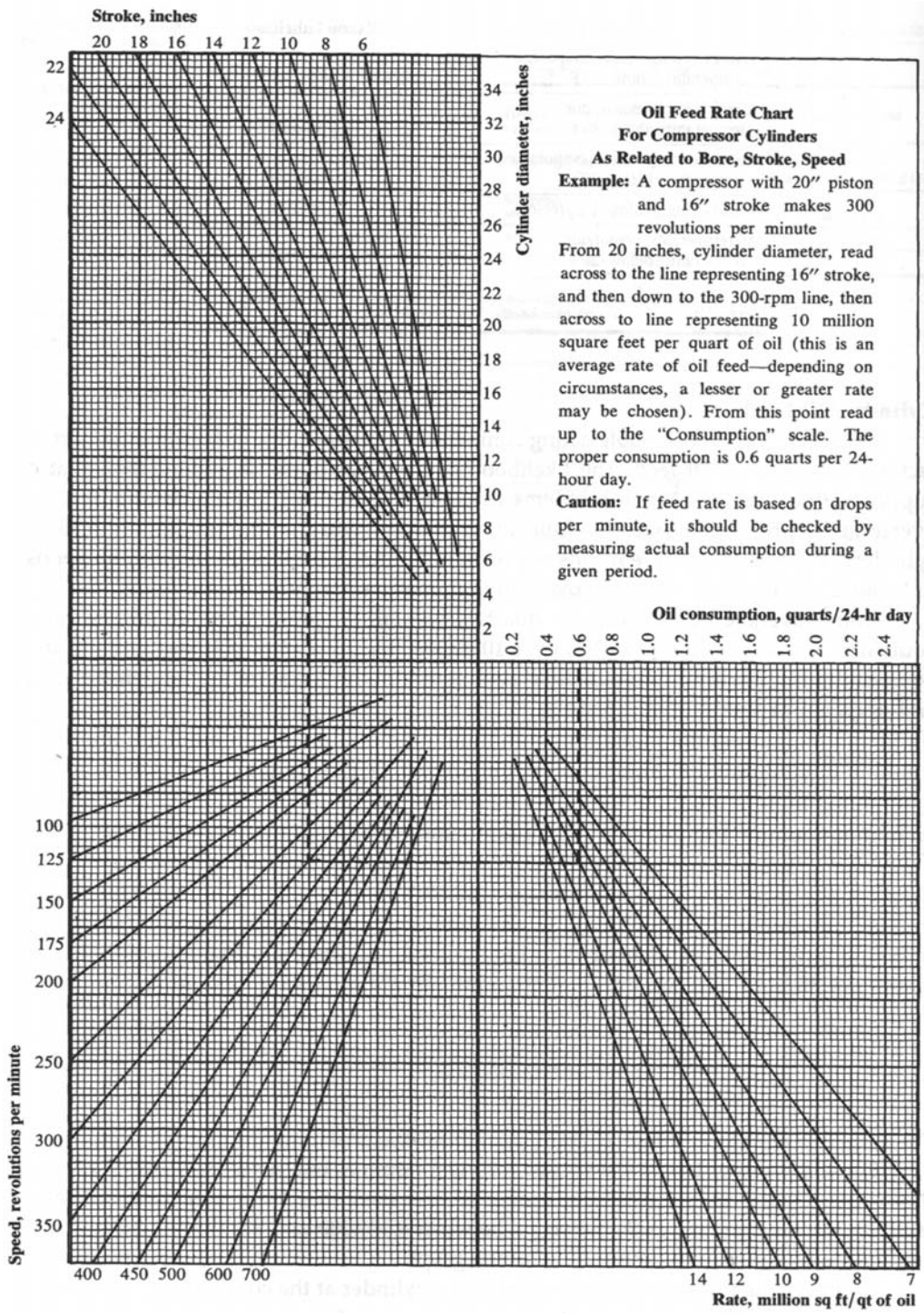
Stroke, inches
20 18 16 14 12 10 8 6
22
24
Cylinder diameter, inches
34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2
Oil Feed Rate Chart
For Compressor Cylinders
As Related to Bore, Stroke, Speed
Example: A compressor with 20″ piston and 16″ stroke makes 300 revolutions per minute
From 20 inches, cylinder diameter, read across to the line representing 16″ stroke, and then down to the 300-rpm line, then across to line representing 10 million square feet per quart of oil (this is an average rate of oil feed—depending on circumstances, a lesser or greater rate may be chosen). From this point read up to the "Consumption" scale. The proper consumption is 0.6 quarts per 24-hour day.
Caution: If feed rate is based on drops per minute, it should be checked by measuring actual consumption during a given period.
Oil consumption, quarts/24-hr day
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
100
125
150
175
200
250
300
350
Speed, revolutions per minute
400 450 500 600 700
14 12 10 9 8 7
6
Rate, million sq ft/qt of oil

Figure 15-19. Oil feed rate to double-acting compressor cylinders.

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amount of oil consumed during the run can be noted. The feed rate can then be increased or decreased to conform to the predetermined value.

Many lubrication systems are equipped with sight-feed oilers by which the flow of oil to the cylinders, in drop form, can be observed. These devices show whether the lubrication system is operating properly and, in drops per minute, give some indication of the feed rate. While the sight-feed oiler can be very helpful in the making of a trial feed adjustment, it should not be relied upon as the sole determining factor in feed regulation.

Size of the oil drop is subject to considerable variation. The number of drops per quart depends on the oil's viscosity and temperature, the diameter and cleanliness of the oil discharge orifice, and the properties of the sight-feed medium. Since differences in oil-drop size have a pronounced effect on the feed rate, the number of drops that pass per minute may not indicate the feed rate accurately. When the feed rate is checked, therefore, it should be done by actual measurement of the added oil in the manner described above.

Assume, for example, that a new compressor is computed to require 0.72 quarts of oil per 24-hour day. Oil-drop diameter in the sight-feed is estimated at 3/16." Table 15-6 shows that 16,700 of these drops are required for one quart. In 24 hours, therefore, 0.72 × 16,700, or about 12,000, drops should be fed. This is approximately 8 drops per minute. Obviously, if the cylinder were supplied by two oilers, each should be adjusted to feed 4 drops per minute.

Table 15-6. Oil feed rate to double-acting compressor cylinders (approximation only).

GUIDE TO OIL FEED RATE

Compressor Cylinders

1 quart of oil will lubricate the sweep of piston over approximately 10,000,000 square feet of cylinder surface.

$$\frac{B \times S \times N \times 62.8}{10{,}000{,}000} = Q$$

B = bore (inches)
S = stroke (inches)
N= rpm
Q = quarts of oil per 24-hour day

Effect of Oil Drop Size on Feed Rate

Diameter of drop, inches	Volume of drop, cu in	Drops per quart	Drops/minute for rate of 1 qt/24 hr
1/16	0.00013	454,000	315
1/8	0.00102	56,600	39
3/16	0.00345	16,700	11.5
1/4	0.00818	7,070	4.9
5/16	0.01598	3,620	2.5
3/8	0.02761	2,090	1.5

This table should be used only as a guide. It illustrates how greatly drop size influences actual oil feed rate. Since it is almost impossible to measure drop size exactly, feed rate should be checked carefully against actual consumption during a given period.

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How closely the applied feed rate meets actual cylinder lubrication requirements should also be checked. This can be done by examination of internal surfaces, such as cylinder walls or exhaust and intake valve parts. Properly lubricated, these surfaces should be covered with a thin, even film of oil. There should be no evidence of oil accumulation.

Probably the most obvious symptom of over-lubrication is the appearance of little oil puddles in low spots in the valve boxes. It may also be advisable to examine the cylinders.

If the cylinder surfaces are wiped with a piece of cigarette paper, oil should stain the paper evenly, but should not soak it. If the paper is dry or unevenly spotted, the feed rate is too low; if the paper is saturated, the feed rate is too high. Where necessary, the feed rate should be adjusted to provide not more than the minimum of lubricant.

LUBRICATION OF GAS ENGINES*

Gas engines with integrally mounted process gas compressors are shown in Figures 15-20 and 15-21. The general maintenance guidelines issues by major manufacturers of gas engines show both similarities and differences. Nevertheless, the equipment engineer or gas engine operator should be guided by customary practices and experience. To that end, let's investigate such issues as oil drain intervals, filter life, port deposits, and component lives.

Oil Drain Intervals

The majority of manufacturers have no specific recommendations regarding lube oil drain intervals because requirements vary considerably with the type of installation. Therefore, good operating procedures dictate that oil samples be taken from the crankcase periodically to determine acidity, type of contaminants, and general condition of the oil. This information should be recorded and used to determine proper oil drain intervals.

Experienced major suppliers and manufacturers are providing a lube oil analysis service that can be shown to represent an excellent, cost-effective means of monitoring the condition of the oil and

Filter Life

As in the oil drain intervals, filter life will vary with operating conditions and the type of filter used. As a guide, the interval between filter changes should not exceed one year. Oil filters should be changed in any case whenever there is an increased pressure differential of 15 to 20 lbs/in^2 across the filter or when necessary to conform to the recommendations of the filter manufacturer.

Ring Life

Ideally, the engine should not have to be overhauled except at five-year intervals. In most low-BMEP engines, it is possible to achieve a five-year ring life. In high-BMEP en-

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Source: Exxon Company, U.S.A.; Houston, Texas: Publication DG-6D, 1995.

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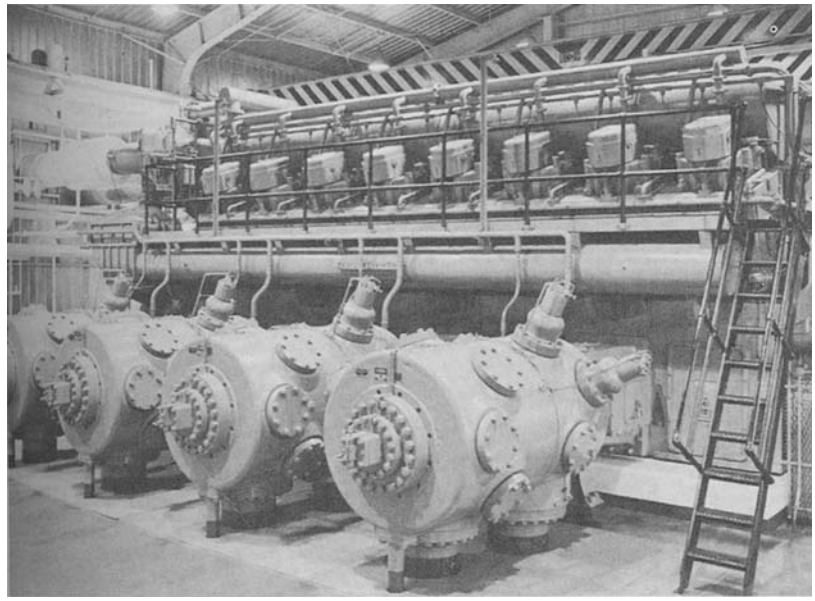

Figure 15-20. This Cooper-Bessemer model V-250 with 16 power cylinders is rated at 5500 hp. Unit is equipped with eight GT pipeline cylinders and is on transmission duty in New York State.

gines, five years between overhauls is possible under favorable conditions, but three to four years is more common. Of course, unfavorable conditions—e.g., operating outside engine design parameters, high ambient temperatures, poor maintenance practices - may make more frequent overhauls necessary.

Valve Life

The valves in four-cycle engines, like the piston rings, should not have to be changed within a five-year overhaul period. This, of course, applies under very favorable conditions. Some engines are subject to valve wear that reduces this life, and some manufacturers recommend replacement at earlier intervals. See Figure 15-22.

Port Deposits

It should not be necessary to punch carbon from ports more frequently than 10,000-12,000 hours (15-18 months). In many installations using superior oils, there is no need to punch carbon between major overhauls.

LUBRICANT RECOMMENDATIONS FOR NATURAL GAS ENGINES

The recommendations in Table 15-7 are made by Exxon Company U.S.A., based upon this company's experience with the engines and lubricants involved. The recommendations are those that would normally apply; if experience indicates abnormally severe conditions, it may be necessary to reduce the oil drain interval or recommend an oil of higher detergency. For each type of equipment, the Exxon lubricant listed first is the primary recommendation. Where an OEM (original equipment manufacturer) lubricant recommendation differs from Exxon's, the OEM recommendation must take precedence.

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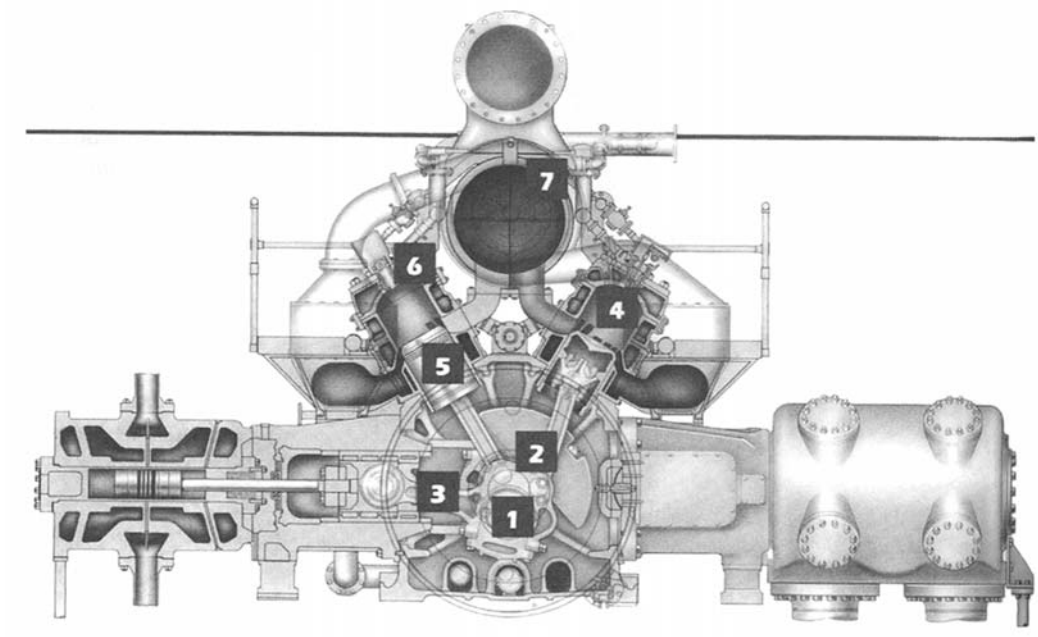

1 Crankshaft The crankshaft is forged from alloy steel and is bedded from the side, allowing easy access without removing the top half of the engine.

2 Main Engine Bearings Bearings are designed to permit maximum bearing area. Materials provide maximum load-carrying capability to give long life with excellent fatigue resistance.

3 Connecting Rods Connecting rods are an articulated design with all forces acting in the same plane. The rod is a one-piece forging with H-column construction for strength.

4 Power Cylinders Power cylinders on smaller-bore engines are one-piece cast iron. For the extra strength required on large-bore engines, the cylinders consist of a one-piece block for each bank of the engine, with individual cylinder liners. The designs incorporate porous chrome bores with intake and exhaust porting located to achieve maximum fuel mixing and high-efficiency scavenging. Two-point oil injection gives an even flow on the bore surface.

5 Power Pistons Each power piston features a one-piece, "cocktail shaker", oil-cooled design with a hemispherical cap and six compression rings.

6 Power Cylinder Heads The one-piece heads are water-cooled, with a hemispherical design to match the piston crown.

7 Turbocharger There are several models of turbochargers, designed and built by Cooper-Bessemer, to provide an exact match with the engine for optimum operating performance.

Figure 15-21. Principal components of Cooper-Bessemer integral gas engine/reciprocating compressor unit.

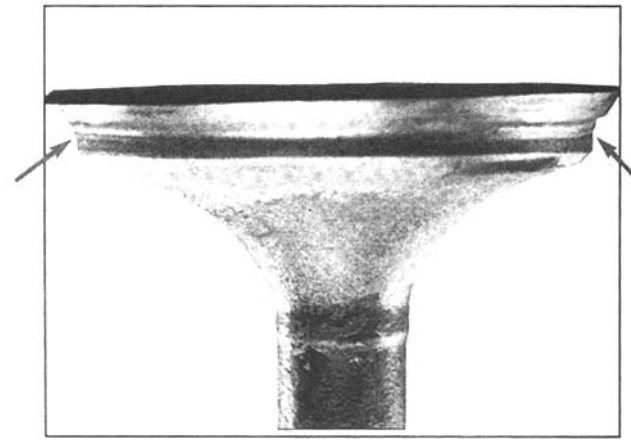

Figure 15-22. Gas engine valve with indications of wear. Recess on the valve face indicates valve beat-in.

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Table 15-7. Lube recommendations for gas engines.

Engine Make and Model	2-Cycle or 4-Cycle	Typical Service	Lube Recommendation
AJAX			
EA			
DP	2	Mild	ESTOR AGX
C-42			ESTOR GA
DPC			
CATERPILLAR			
G349, G348			
G346, G343			
G333, G399	4	Moderately Severe	ESTOR Super, ESTOR GLX-C
G398, G379			ESTOR AGX
G353, G342			
G3300, G3400			ESTOR ELITE
G3500, G3600	4	Severe Service	ESTOR Super
CLARK			
RA RAS, RAT[1]	2	Mild	ESTOR AGX, ESTOR GA
HRA, HRAT, HSRA, TRA	2	Mild (moderately severe with respect to port plugging)	ESTOR AGX, ESTOR GA
BA, HBA, HBAT[1]	2	Mild (moderately severe with respect to port plugging)	ESTOR AGX, ESTOR GA
HLA, HLAT, TLA, TLAB[1]			
TLAC[1]	2	Moderate	ESTOR AGX, ESTOR GA
TLAD			
TVC, TPV[1], TCVA, TCVB[1]	2	Moderate	ESTOR AGX, ESTOR GA
TCVC, TCVD			
CLIMAX			
K-67[1]			
K-75			
(F 1850G)[2]			
V-80[1]	4	High-speed engines generally severe on the lubricant	ESTOR Super
V-85			ESTOR GLX-C
(H 2475G)[2]			
V-122[1]			
V-125			
(L 371 IG)[2]			

NOTES: (1) Models no longer in production.
(2) Model number change only.

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Table 15-7. (Continued)

Engine Make and Model	2-Cycle or 4-Cycle	Typical Service	Lube Recommendation
COOPER BESSEMER			
GMVA, GMVC[1], GMVD[1] GMVE, GMVG[1], GMVH GMW[1], GMWA[1], GMWC[1] GMWD[1], GMWF[1], GMWH[1] GMX[1], GMXA[1] GMXC[1] GMXD[1], GMXE[1] GMXF[1] GMXH[1]	2	Mild (moderately severe with respect to port plugging)	ESTOR AGX[2] ESTOR GA ESTOR Super
QUAD 145 QUAD 155	2	Mild (moderately severe with respect to port plugging)	ESTOR AGX ESTOR GA
V-250[1] V-275 W-330 Z-330	2	Mild (moderately severe with respect to port plugging)	ESTOR Super ESTOR GLX-C ESTOR GA
FVB[1] FVG[1] JS[1] JSA[1] JST[1]	4	Moderately severe	ESTOR Super ESTOR GLX-C
KSV LS[1] LST[1] LSV, LSVB LSVT[1]	4	Moderately severe Duel Fueled	ESTOR Super, ESTOR GLX-C XD-3 Extra 40
INGERSOLL RAND			
PVG[1] XVG[1] JVG[1] KVG[1] SVG[1] KVGR[1] TVS[1] TVR[1] KVS[1]	4	Moderately severe Moderately severe to severe	ESTOR Super[3] ESTOR GA ESTOR Super
KVT, KVH[1] KVR, SYS KVSR, KVSE KVSF	4	Very severe	ESTOR Super

NOTES: (1) Models no longer in production
(2) For BMEP >85psi, ESTOR Ashless preferred
(3) ESTOR Super 40 CAT I, II & III approved

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Table 15-7. (Continued)

Engine Make and Model	2-Cycle or 4-Cycle	Typical Service	Lube Recommendation
ROILINE			
H 540[1]			
H 8441[1]			
F 1500[1]			
F 1850			
H 2000[1]	4	High-speed, very severe	ESTOR Super
H 2470[1]			
L 3000[1]			
L 3230[1]			
L 3460[1]			
L 4000[1]			
SUPERIOR (WHITE)			
6G - 825 12G - 825			
6GTL (B) 12GTL (B)			ESTOR Super
8G - 825 12SGT (B)	4	Moderate to high speed, very severe	ESTOR Select[2]
8GTL (B) 16G - 825			ESTOR GLX-C
8SGT (B) 16GTL (B)			
16SGT (B)			
1700, 2400 Series	4	Moderate to high speed, very severe	Refer to Superior's Engineering Std-1005
WAUKESHA			
VSG, F11G, GSI, GSID			GLX-C
VGF F18, H24, L36, P48 G. GL. GLD			ESTOR Select
Intermediate F817, F1187G			ESTOR Super, ESTOR Elite
VHP 2895, 3521, 5108, 5790, 7042, 9390 G, GSI (Rich Burn or Lambda 1)		High-speed, very severe	Estor GLX-C
VHP 2895, 5108, 5790, GL (Lambda 1.5-2)			
VHP 3521, 5115, 7042, 9390 GL Turbo & Lean Burn (Lambda 1.5-2)			Estor Select
AT25/27 8L 12VGL0.35% Min			ESTOR GLX-C
WORTHINGTON			
CGG	4	Generator engine, severe service	ESTOR Super, ESTOR GLX-C
SLHC	4	Moderately severe	ESTOR Super, ESTOR GLX-C
LTC			
ML			
SUTC	2	Mild service	ESTOR GA
UTC			ESTOR AGX
VEE			

NOTES: (1) Models no longer in production.
(2) Recommended for lean/clean burn applications.

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Tables 15-8 and 15-9 contain data on the physical characteristics of suitable, premium-grade lubricants. In the case of Exxon, ESTOR is the trademark for a line of natural gas engine lubricants that covers the entire range of gas engine lubrication requirements. Estor gas engine oils are suitable for both crankcase and cylinder lubrication. They are highly effective in suppressing ring-zone and port deposits and crankcase sludge.

These products, are formulated from specially selected solvent-extracted naphthenic basestocks, which have inherent resistance to carbon formation.

The ESTOR line of gas engine oils offers a wide selection of viscosities to meet a broad range of OEM and operational requirements. For better operation at low temperatures, ESTOR GA, ESTOR GLX-C, and ESTOR Super are available in an SAE 15W-40 multigrade, as well as an SAE 40 grade, whereas the other ESTOR products are single grades typically at the low end of the SAE 40 viscosity range, which is acceptable to the major engine manufacturers.

The distinct features of each grade can be summarized as follows:

ESTOR Elite—A full-synthetic gas engine oil designed for superb performance under the most severe operational conditions; approved against Waukesha cogeneration requirement (Figures 15-23 and 15-24).

Table 15-8. Typical inspections for four gas engine lubricants.

Typical Inspections	ELITE	SUPER		SELECT	GLX-C	
ESTOR Grade	20W40	40	15W-40	40	40	15W-40
Viscosity,						
cSt @ 100°C	13.2	13.2	14.4	13.5	13.2	14.3
cSt @ 40°C	99	126	108	133	128	108
cP @ -15°C, CCS	3500	—	3250	—	—	3300
Viscosity index	132	98	136	95	96	135
Flash point, COC,						
°C	330	246	205	240	246	205
°F	446	475	401	464	475	401
Pour point,						
°C	<-50	-15	-24	-15	-21	-24
°F	<-58	5	-11	+5	-5	-11
Sulfated ash, mass %	0.45	0.45	0.45	0.95	0.40	0.40
Total Base Number,						
ASTM D 2896	5.2	5.2	5.4	9.8	3.2	3.4
Phosphorus, ppm	280	280	280	290	700	700
Density, lb/gal	6.99	7.37	7.33	7.43	7.38	7.34
Gravity, °API	36.9	28.4	29.1	27.0	28.2	29.1

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ESTOR Super—API CD universal lubricant recommended for all natural gas engines approved against Waukesha cogeneration requirement (Figures 15-25 and 15-26).

ESTOR Select—premium medium-ash lubricant for lean-burn and cogeneration applications; approved against Waukesha cogeneration requirement (Figures 15-27 and 15-28).

ESTOR AGX—premium ashless lubricant for two-cycle gas engines

ESTOR GLX-C—detergent dispersant lubricant with 0.4% ash; highly recommended for most four-cycle gas engines

ESTOR GA-40—ashless formulation with a highly effective anti-wear additive (Figures 15-29 and 15-30).

ESTOR GMA—Super-premium low ash lubricant formulated with a proprietary balanced additaive package for excellent control of oxidation, nitration, deposits and wear

ESTOR Grade	GLX-C	GA-40	AGX-40	GMA-40
Viscosity,				
cSt@ 100°C	13.2	13.5	13.5	13.5
cSt @ 40°C	124	133	135	133
cP @ -15°C, CCS	—	—	—	—
Viscosity index	96	96	95	95
Flash point, COC,				
°C	246	246	250	240
°F	475	475	482	464
Pour point,				
°C	-21	-18	-21	-21
°F	-5	0	-5	-5
Sulfated ash, mass %	0.40	0.14	<0.1	0.45
Total Base Number,				
ASTM D 2896	3.2	1.0	2.5	5.0
Phosphorus, ppm	270	690	940	300
Density, lb/gal	7.38	7.39	7.41	7.40
Gravity, °API	28.2	27.9	27.5	27.6

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FIGURE A. **ESTOR Elite Provided Outstanding Wear Protection in a Waukesha Engine Field Test**
Engine Model: Waukesha 3521 GSIU / Rated Power: 1067 BHP @ 1200 rpm / Operating Conditions: 900 BHP @ 1200 rpm

Test Conditions	
3965 Hours	
Coolant Temperature	250°F
Oil Temperature	160°F

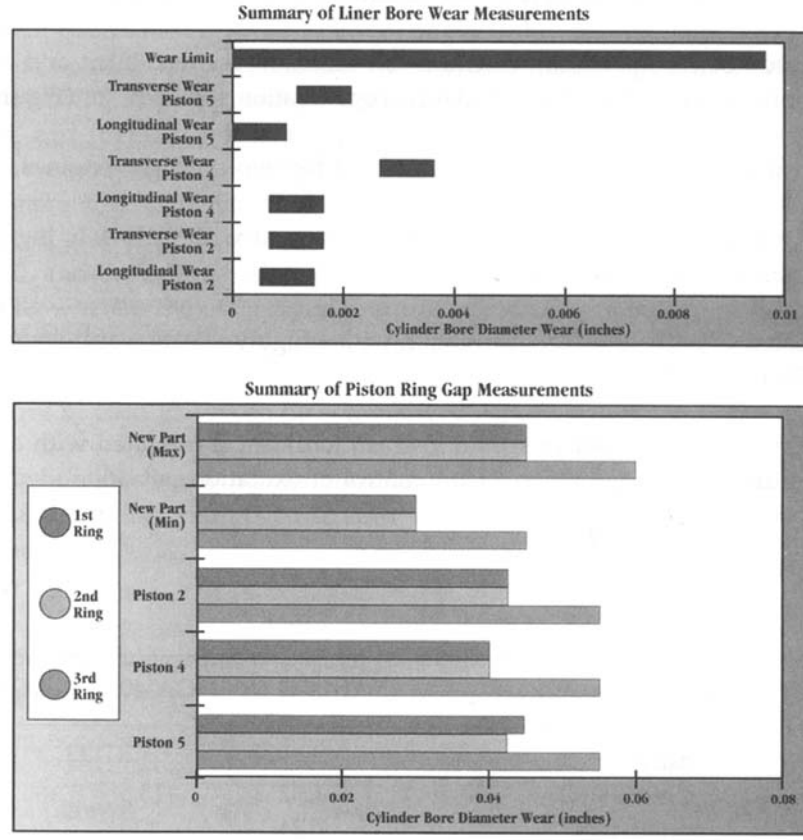

FIGURE B. **ESTOR Elite Provided Superior Deposit Control in a Caterpillar 3304 Engine Test, Compared with Two Competitive Gas Engine Oils**

Test Conditions
250 Hours
Full head
Reduced oil sump capacity
Air/Fuel ratio to maximize Nitration

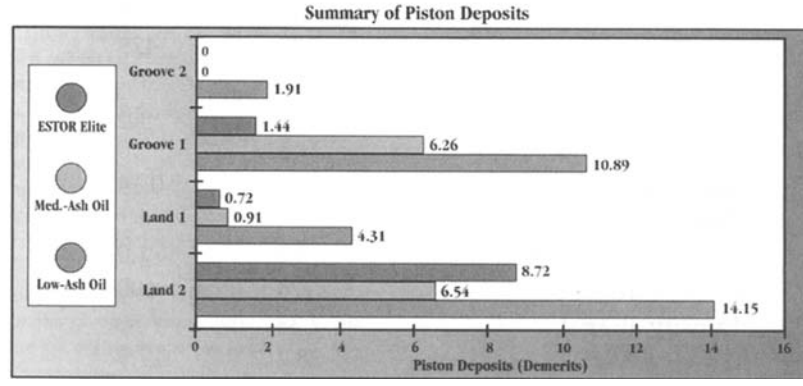

Figure 15-23. Performance comparison, ESTOR Elite gas engine oil.

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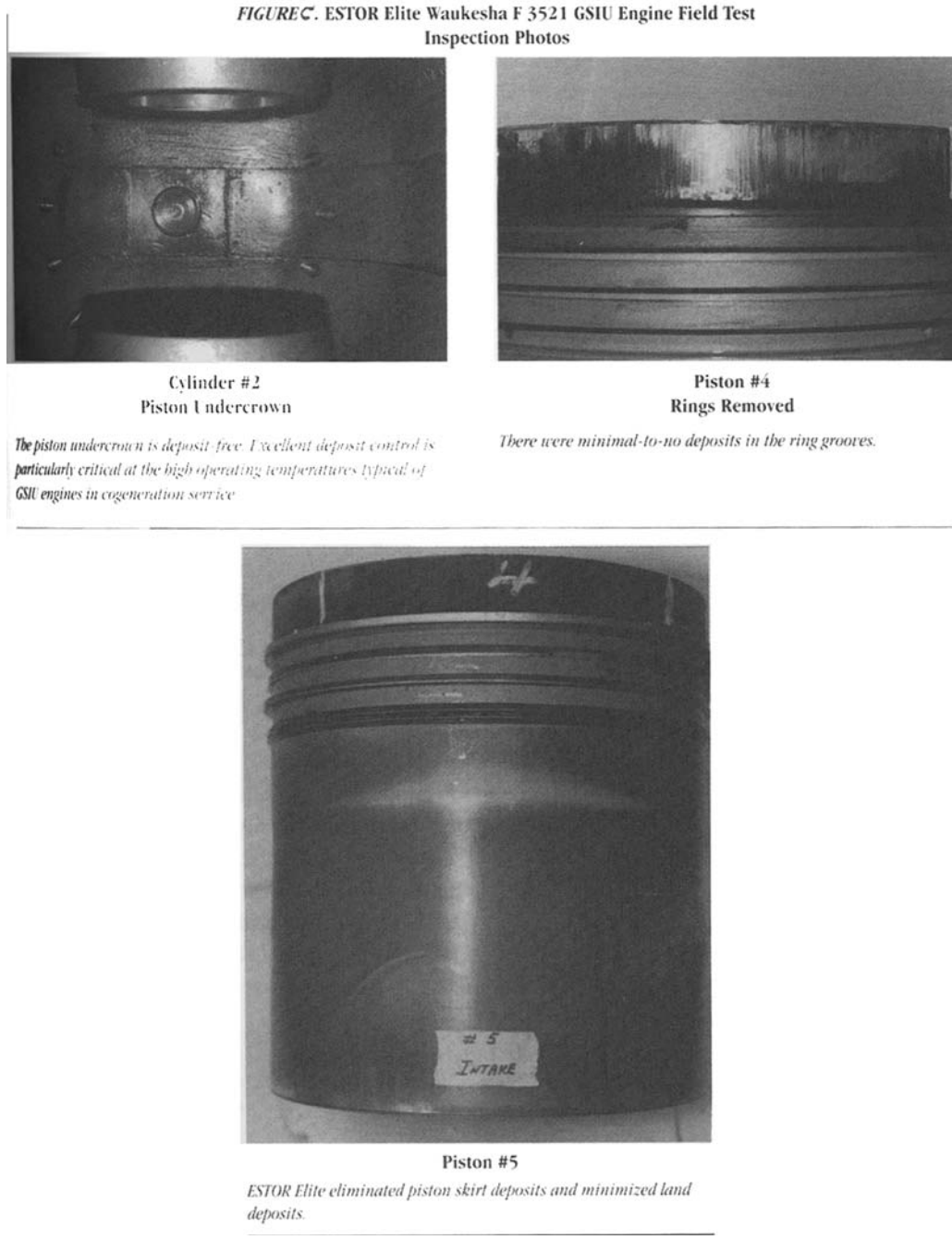
FIGURE C. ESTOR Elite Waukesha F 3521 GSIU Engine Field Test
Inspection Photos
Cylinder #2
Piston Undercrown
The piston undercrown is deposit-free. Excellent deposit control is particularly critical at the high operating temperatures typical of GSIU engines in cogeneration service
Piston #4
Rings Removed
There were minimal-to-no deposits in the ring grooves.
#5
INTAKE
Piston #5
ESTOR Elite eliminated piston skirt deposits and minimized land deposits.

Figure 15-24. Performance photos, ESTOR Elite gas engine oil.

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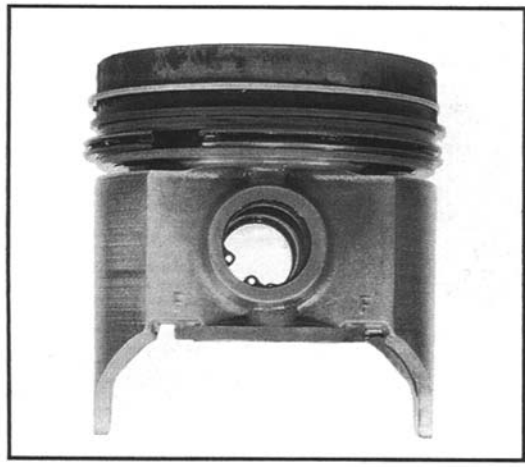
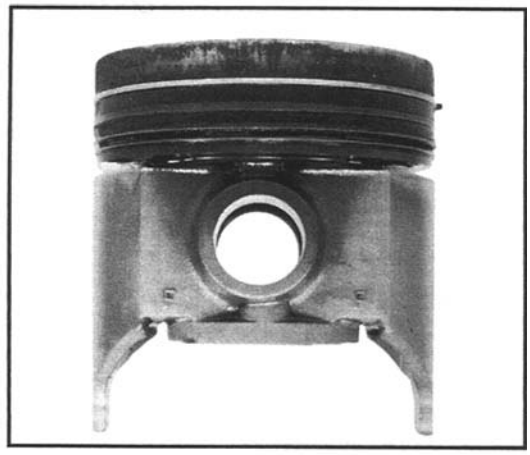


ESTOR Super



Commercial Gas Engine Oil "A"

Figure 15-25. ESTOR Super demonstrates outstanding piston deposit control. Pistons removed from a single-cylinder CLR engine after a 140-hour Nitration/Oxidation Inhibition Test clearly show the superiority of ESTOR Super versus a competitive oil in maintaining piston cleanliness.

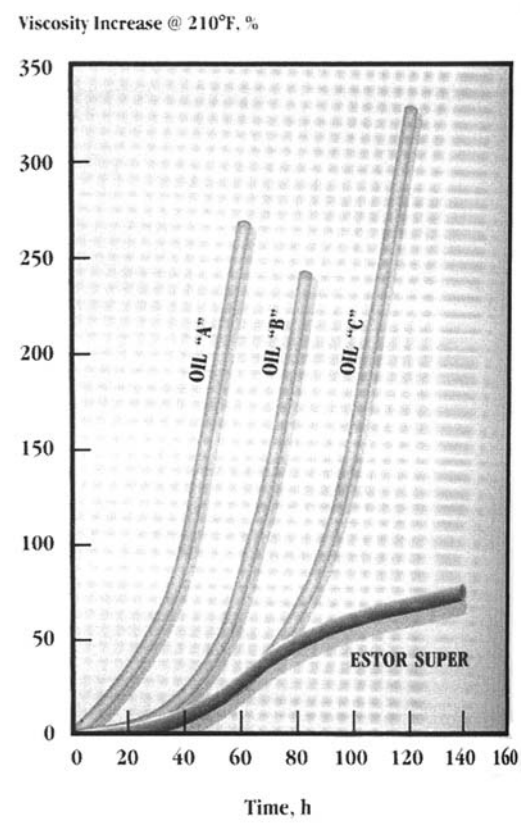


Figure 15-26. Nitration and oxidation inhibition viscosity increase laboratory engine test. The graph illustrates the excellent viscosity control demonstrated by ESTOR Super compared with three competitive commercial gas engine oils in the severe Nitration/Oxidation Engine Test.

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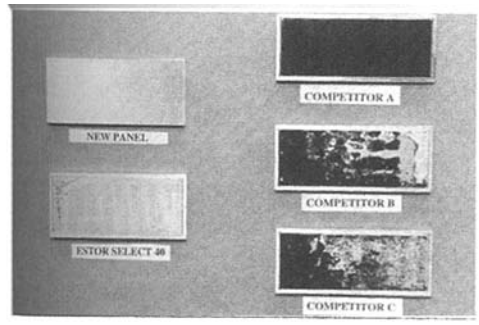
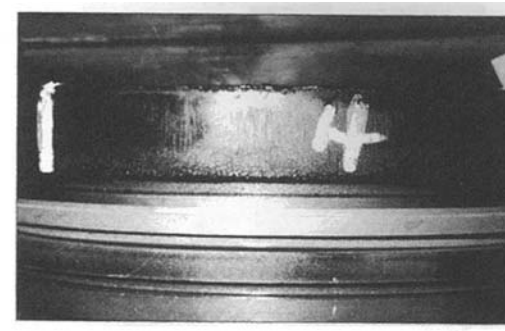


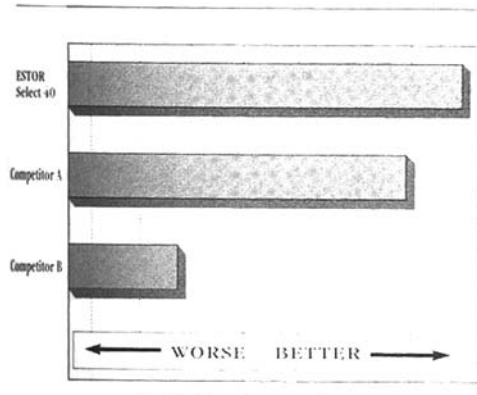
Deposit Control

Testing was completed by heating metal panels to 315 C in order to demonstrate how oxidation of the oil might lead to piston deposits. The panel looks almost like new when tested with ESTOR Select 40, a significant improvement over the competition.



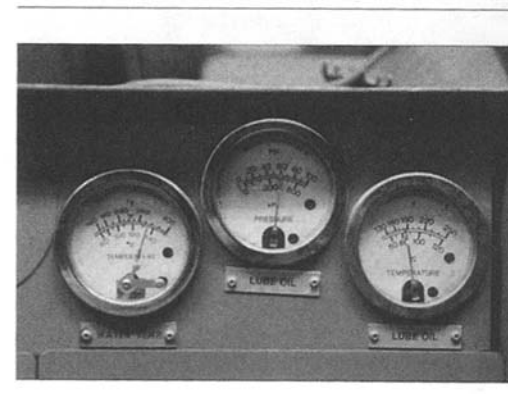
Waukesha L7042 GSIU Piston

As verified by extensive field testing, ESTOR Select 40 produced only minimal carbon deposits, despite being run in the high-temperature environment of cogeneration service.



Oxidation Control

ESTOR Select 40 has a proprietary formulation which is designed to resist oxidation and nitration. Testing has demonstrated that this formulation offers excellent oxidation control, which leads to extended oil life.



Waukesha L7042 GSIU Control Panel

ESTOR Select 40 was proven to maintain outstanding oxidation control in a cogeneration application, where jacket water temperatures were pushed to 265°F.

Figure 15-27. Performance comparison for ESTOR Select gas engine oil.

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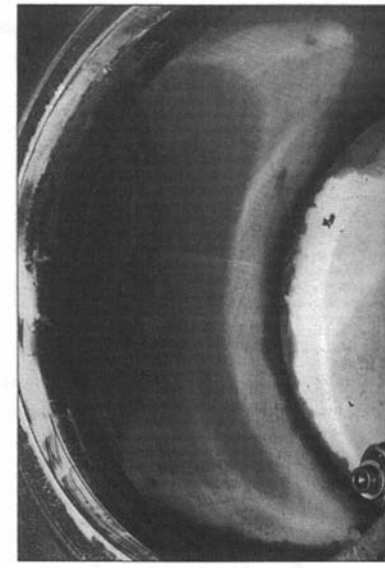
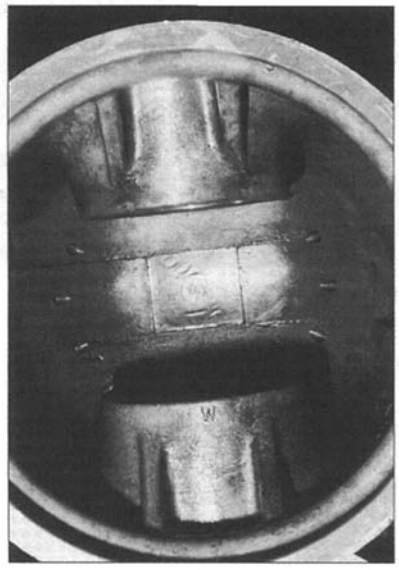
Waukesha L7042 GSIU Exhaust Valve

Valve shows a controlled level of ash deposit with minimal valve recession.



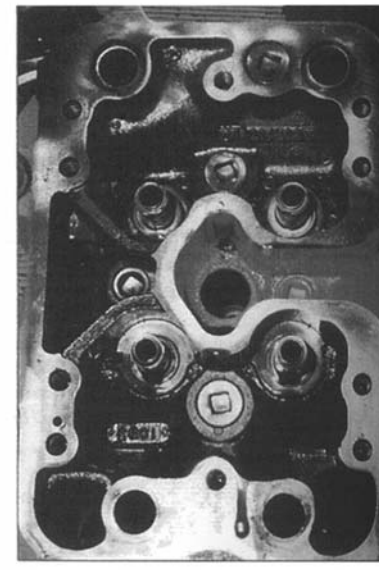
Waukesha L7042 GSIU Cylinder Liner

Good anti-wear performance allows ESTOR Select 40 to protect metal surfaces, as shown by this cylinder liner, which has maintained good crosshatching.



Waukesha L7042 GSIU Piston Under crown

Piston undercrowns exhibit low varnish/lacquer to ensure good heat dissipation.



Waukesha L7042 GSIU Valve Deck

Valve deck is sludge-free.

Figure 15-28. Performance photos, ESTOR Select gas engine oil.

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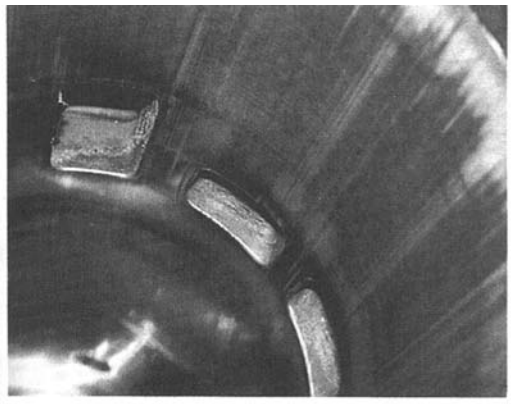
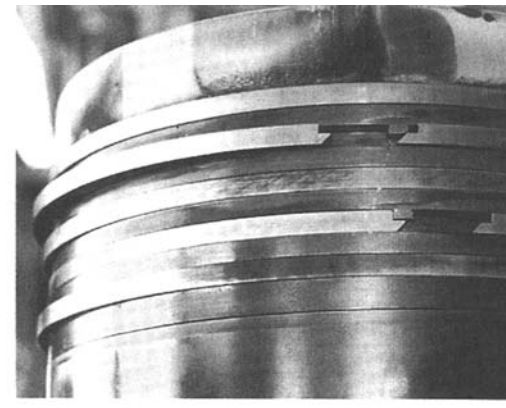


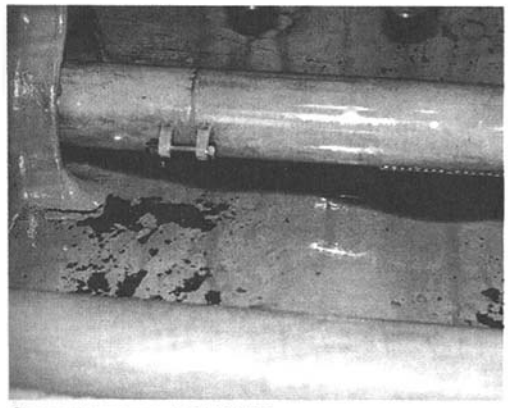
Clark TLA 10
9156 Hours on ESTOR GA 40
Ports, Cylinder #3

Intake and exhaust ports show minimal deposits, thereby eliminating any need for cleaning.



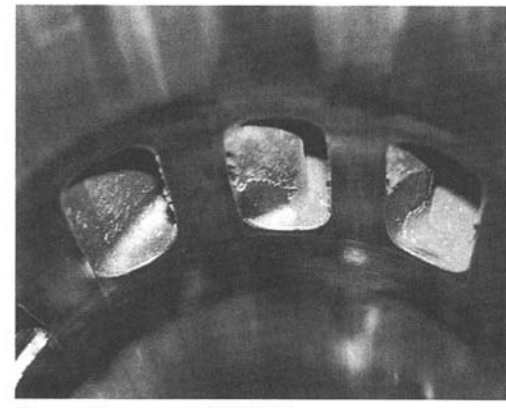
Clark TLA 10
9156 Hours on ESTOR GA 40
#7 Piston, Ring Zone

Crownland carbon is low. Rings move freely and show minimal wear, thus preventing the need for premature overhaul.



Cooper-Bessemer GMWC 10
8000 Hours on ESTOR GA 40
Crankcase

Crankcase is sludge-free.



Cooper-Bessemer GMWC 10
8000 Hours on ESTOR GA 40
Exhaust Ports, #2L Cylinder

Port deposits are minimal – no cleaning needed.

Figure 15-29. Performance photos, ESTOR GA 40 gas engine oil.

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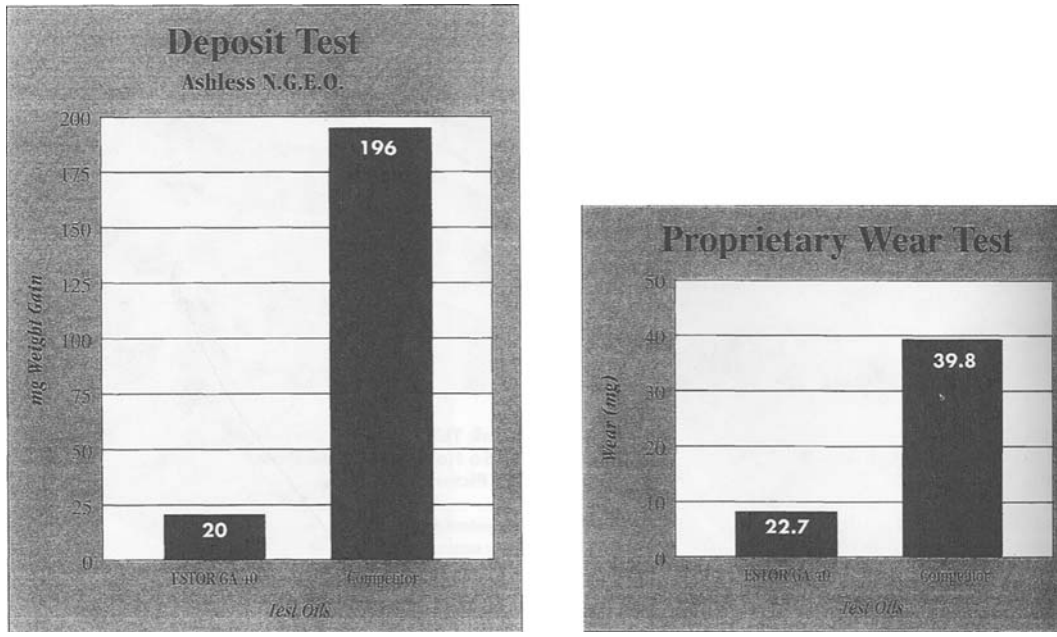

Figure 15-30. Deposit and wear test comparisons, ESTOR GA 40 vs. competitor.

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